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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIII. No. 1. NOVEMBER 1892.

(No 1 — 8)

*** Fellows of the Society are informed that post-cards containing the titles of papers to be read at the evening meetings will be sent to those who shall express their wish to receive them. Fellows desiring to receive the post-cards are requested to send their names to the Assistant-Secretary, Mr. W. H. Wesley, Burlington House, London, W.

In order to enable the Secretaries to prepare complete lists in time for the issue of the post-cards, authors are particularly requested to send in their papers not later than the Tuesday preceding the day of meeting.

Fellows are informed that Vol. L. of the *Memoirs* is now published, and may be had on application at the apartments of the Society.

The volumes of the *Memoirs* are sent post-free to any Fellow who is entitled to receive them, on receipt of a written request to that effect, addressed to the Assistant-Secretary, Burlington House, London, W.

The price of Vol. L. to the public is 12*s.* 6*d.*

Royal Astronomical Society.

NOTICE TO FELLOWS INTENDING TO EXHIBIT LANTERN AND MICROSCOPICAL SLIDES.

Attention to the following details would greatly facilitate the exhibition of such slides at the meetings of the Society :—

1. Place a small disc of white paper on the right-hand upper corner of the slide when held in the hand in the position in which it is to appear on the screen. The lanternist will then place it in the correct position for the lantern.

2. Indicate upon this disc the order in which each slide is to be shown (whether for the lantern or microscope).

3. Slides showing spectra should be blocked out with black paper, especially if two are to be exhibited on the screen simultaneously.

4. So far as it is possible, all slides should be made on "lantern-plates," ordinary negatives being too dense, even in their transparent parts, for the optical lantern, but especially so when requiring microscopic projection.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LIII. NOVEMBER 11, 1892. No. 1

E. B. KNOBEL, President, in the Chair.

The Rev. James Barnes Brearley, M.A., F.R.G.S., St. James's Church, Oldham, Lancashire;
Herbert Hancock, M.A., F.R. Met. Soc., Bancroft's School, Woodford, Essex;
Thomas Torrens Knowles, M.A., Royal Grammar School, Lancaster;
Alfred Thomas Odell-Sorrell, St. Mary's Grove, Chiswick, W.;
Edward Stroud, Prisca Coborn Foundation School, Tredegar Square, E.;
John Tatlock, jun., M.A., New York, U.S.A.,

were balloted for and duly elected Fellows of the Society.

Professor W. L. Elkin, Yale College, New Haven, Conn., U.S.A.;
Professor J. C. Kapteyn, Observatory, Groningen, Holland;
Professor Hugo Seeliger, Observatory, Munich, Bavaria;
Dr. Hermann Struve, Observatory, Pulkowa, Russia,

were balloted for and duly elected Associates of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Joseph Ibbitson Berry, 20, Alwyne Road, Canonbury, N. (proposed by W. S. B. Woolhouse);
Martin Brendel, Ph.D., Privat-docent of the University, Greifswald, Germany (proposed by H. H. Turner);
Ernest Gould Dixon, Teacher and Graduate of the College of Preceptors, 78, Alderney Street, S.W. (proposed by John Newton);
Harold Dennis Taylor, Optical Manager to Messrs. T. Cooke and Sons, 20, Bootham Terrace, York (proposed by Albert Taylor).

Two hundred and ten presents were announced as having been received since the last meeting, including, amongst others,

part of a series of photographic portraits of the Presidents of the Society, made and presented by Mr. W. Schooling; C. Flammarion, La planète Mars, presented by the author; Barlow and Bryan, Elementary Mathematical Astronomy, presented by Mr. W. T. Lynn; A. Guillemin, Autres Mondes, presented by the author; Catalogue of Proper-motion Stars, by J. G. Porter, presented by the Cincinnati Observatory; Oxford University Observatory, Researches in Stellar Parallax by the aid of Photography, Part 2, presented by the Observatory; H. Gyldén, Nouvelles recherches sur les séries employées dans les théories des Planètes, presented by the author; E. L. Trouvelot, Drawing of a portion of the Milky Way, presented by M. Trouvelot (per Mr. A. Marth); Lick Observatory, Photographs of the Moon and *Jupiter* (enlarged positives on glass), presented by the Observatory; Sydney Observatory, Photographs of portions of the Moon and of the region surrounding η *Argûs* (enlargements on paper), presented by Mr. H. C. Russell; Astronomische Gesellschaft, Catalog, Zone + 50° bis 55° (Cambridge, Mass.), presented by the Society; Specola Vaticana, Pubblicazioni I. and II., presented by the Observatory; von Kuffner'sche Sternwarte, Publicationen, Band II., presented by the Observatory; J. Bossert, Catalogue de 3950 étoiles (supplément à l'Histoire Céleste de Lalande), presented by the author.

On the Variation of Latitude, as indicated by Recent Observations at the Royal Observatory, Greenwich. By W. G. Thackeray and H. H. Turner, M.A., B.Sc.

The publication of a Star Catalogue at Greenwich has generally been an occasion for discussing the systematic errors of that and of previous catalogues, from comparisons *inter se*, or with catalogues of other observatories. The last Greenwich Catalogue (Ten-Year, 1880) is, for instance, readily comparable with Stone's Cape Catalogue, 1880, and the comparison has an important bearing on the determination of refraction. It has, indeed, already been made, but the discussion is not quite complete, though it is hoped soon to publish the results. But a somewhat new departure has been made in connection with the Ten-Year Catalogue, in the comparison of the N.P.D.s for different years with the mean. The investigation was, from the nature of the case, limited to those stars which had been well observed at different epochs throughout the ten years; and in practice only those stars were included which had been observed in at least five years out of the ten. For such stars the annual means for N.P.D., formed in the computation sheets during the process of reduction to 1880·0, were compared with the finally adopted result for N.P.D., and the excesses tabulated under the respective years, with a view to the detection of systematic error. Subsidiary arrangements of these quantities were made both in R.A. and N.P.D., and the results are shown in the following tables.

Table I.

Excess of Annual Mean N.P.D. over Adopted Result for N.P.D., arranged according to Right Ascension.
(The suffixes indicate the number of observations.)

R.A. h h	1877.	1878.	1879	1880.	1881.	1882.	1883.	1884.	1885.	1886.
0— 6	$+0''.03_{393}$	$+0''.09_{393}$	$+0''.07_{381}$	$+0''.01_{471}$	$-0''.06_{471}$	$-0''.04_{430}$	$+0''.06_{414}$	$-0''.26_{425}$	$+0''.04_{380}$	$-0''.01_{483}$
6—12	$-0''.02_{241}$	$-0''.02_{317}$	$+0''.09_{237}$	$-0''.04_{215}$	$+0''.06_{328}$	$+0''.09_{422}$	$+0''.04_{381}$	$+0''.01_{314}$	$-0''.08_{315}$	$+0''.01_{371}$
12—18	$+0''.10_{268}$	$+0''.04_{316}$	$-0''.09_{325}$	$-0''.13_{340}$	$+0''.06_{278}$	$+0''.05_{329}$	$+0''.17_{300}$	$+0''.02_{305}$	$-0''.13_{314}$	$-0''.06_{322}$
18—24	$+0''.11_{472}$	$+0''.12_{523}$	$+0''.01_{517}$	$-0''.16_{514}$	$-0''.11_{580}$	$-0''.03_{412}$	$+0''.02_{550}$	$+0''.09_{544}$	$-0''.09_{500}$	$-0''.05_{498}$
Mean	$+0''.06_{1373}$	$+0''.06_{1564}$	$+0''.02_{1451}$	$-0''.08_{1689}$	$-0''.03_{1647}$	$+0''.02_{1593}$	$+0''.06_{1643}$	$+0''.02_{1589}$	$-0''.06_{1568}$	$-0''.03_{1670}$

TABLE II.

Excess of Annual Mean N.P.D. over Adopted Result for N.P.D., arranged according to N.P.D.

(The suffixes indicate the number of observations.)

N.P.D.		1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.
°	°	″	″	″	″	″	″	″	″	″	″
30 to	40	-0.59_{6}	...	$+0.36_{3}$	-0.27_{7}	$+0.21_{7}$	-0.17_{11}	$+0.02_{12}$	$+0.39_{14}$	-1.04_{1}	-0.25_{6}
20	30	-0.47_{6}	-0.12_{5}	-0.27_{7}	-0.14_{19}	$+0.12_{18}$	-0.26_{13}	$+0.11_{46}$	-0.14_{13}	-0.03_{61}	$+0.20_{59}$
10	20	-0.08_{12}	$+0.29_{7}$	$+0.11_{10}$	-0.04_{12}	-0.01_{12}	-0.07_{22}	-0.09_{39}	-0.01_{40}	$+0.02_{37}$	-0.14_{38}
0	10	-0.06_{162}	-0.13_{109}	-0.35_{97}	-0.23_{140}	-0.02_{161}	$+0.03_{169}$	$+0.24_{200}$	$+0.31_{188}$	-0.14_{153}	$+0.12_{124}$
0	10	$+0.07_{200}$	$+0.08_{140}$	$+0.09_{140}$	-0.11_{193}	-0.09_{185}	-0.05_{206}	$+0.19_{230}$	$+0.12_{184}$	-0.22_{178}	-0.11_{163}
10	20	$+0.18_{77}$	0.00_{92}	-0.13_{80}	$+0.03_{94}$	-0.08_{76}	-0.06_{43}	$+0.01_{47}$	$+0.15_{57}$	-0.11_{57}	$+0.02_{62}$
20	30	$+0.05_{139}$	$+0.06_{140}$	-0.03_{155}	-0.15_{190}	-0.04_{200}	-0.01_{140}	$+0.11_{93}$	$+0.26_{92}$	-0.14_{75}	$+0.08_{106}$
30	40	-0.19_{18}	$+0.19_{23}$	-0.08_{19}	-0.13_{30}	-0.20_{21}	-0.26_{21}	$+0.18_{26}$	$+0.18_{23}$	$+0.21_{17}$	$+0.08_{25}$
40	50	$+0.01_{50}$	$+0.20_{34}$	$+0.02_{22}$	-0.04_{38}	-0.30_{41}	-0.12_{43}	$+0.03_{43}$	$+0.16_{59}$	$+0.12_{70}$	-0.15_{65}
50	60	$+0.02_{127}$	$+0.01_{133}$	-0.11_{141}	-0.12_{136}	$+0.04_{111}$	0.00_{85}	$+0.14_{77}$	-0.05_{62}	$+0.02_{55}$	$+0.13_{79}$
60	70	$+0.02_{224}$	$+0.10_{259}$	$+0.06_{275}$	-0.08_{299}	$+0.03_{247}$	-0.03_{202}	-0.06_{167}	$+0.03_{199}$	-0.03_{181}	-0.02_{231}
70	80	$+0.03_{161}$	$+0.10_{235}$	-0.10_{205}	-0.10_{214}	$+0.01_{186}$	$+0.06_{214}$	$+0.09_{196}$	$+0.05_{175}$	-0.03_{210}	-0.03_{186}
80	90	$+0.31_{85}$	$+0.09_{128}$	-0.02_{119}	-0.16_{110}	-0.09_{94}	$+0.17_{176}$	$+0.03_{174}$	-0.04_{198}	-0.17_{238}	$+0.04_{246}$
90	100	$+0.07_{54}$	-0.20_{75}	$+0.08_{98}$	-0.17_{108}	-0.10_{92}	$+0.09_{128}$	$+0.15_{191}$	$+0.08_{175}$	-0.10_{145}	-0.13_{186}
100	110	$+0.07_{55}$	-0.07_{88}	$+0.02_{86}$	-0.24_{75}	-0.01_{92}	$+0.01_{107}$	$+0.34_{111}$	-0.09_{101}	-0.22_{102}	$+0.01_{87}$
110	120	-0.30_{42}	$+0.05_{41}$	-0.10_{55}	$+0.04_{48}$	$+0.54_{31}$	$+0.01_{77}$	$+0.26_{54}$	-0.02_{61}	-0.13_{39}	-0.35_{56}
Mean	...	$+0.06_{1418}$	$+0.06_{1509}$	$+0.01_{1544}$	-0.08_{1743}	-0.02_{1574}	$+0.02_{1687}$	$+0.07_{1706}$	$+0.01_{1677}$	-0.07_{1619}	-0.04_{172}

It is not proposed to make any further comment on these tables as they stand in the present paper, the object of which is to give the results of a line of investigation suggested by the inspection of Table I., which affords sufficient evidence in favour of Mr. Chandler's fourteen-monthly period in latitude to make the present note of immediate interest.

Mr. Thackeray's interpretation of Table I. was as follows:— The right ascension of a star is a rough indication of the time of year at which it was observed. We may assume the mean time of observation at Greenwich to be about midway between sunset and 2 A.M., or for our present purpose 10 o'clock P.M.; so that the mean time of observation of the groups 0^h–6^h, 6^h–12^h, 12^h–18^h, and 18^h–24^h would be as follows:—

Group.	Mean R.A.	Mean Epoch of Observation.
h h	h	
0–6	3·0	Dec. 5
6–12	9·0	Mar. 7
12–18	15·0	June 6
18–24	21·0	Sept. 5

If, then, the groups in Table I. are arranged consecutively, placing each column in order under the one to the left, we shall have a rough indication of the systematic changes in N.P.D. arranged in order of time. There is, of course, the considerable error in this assumption that observations in the group 0^h–6^h in any year were made partly at the beginning and partly at the end of the year, whereas we can only assign them to one of these epochs; but for the particular discussion in question the error thus introduced is not too serious, for Mr. Chandler's period of variation (fourteen months) does not differ very largely from a year, and consequently the phases at the beginning and end of the year would not be very different.

But it is to be remarked that the formation of such large groups as those of six hours—corresponding to nearly a quarter of the whole period—considerably diminishes the apparent amplitude of the wave under discussion. [The theoretical apparent amplitude would become about seven-tenths of the original.] Further, stars observed below the pole must be regarded as having an R.A. differing by twelve hours from their tabular R.A., and Table I. must be corrected accordingly. The original comparison with Mr. Chandler's inequality was, however, made without this correction.

Crediting the group 0^h–6^h, therefore, to the end of the year, we get the chronological variation of N.P.D., as in the following table in the column O, where in the column C is given the theoretical variation according to Mr. Chandler's paper in the *Astronomical Journal*, No. 267:—

TABLE III.

Excess of Mean Annual Mean N.P.D. over Adopted Result for N.P.D., arranged for every 6h of Right Ascension and compared with the Theoretical Variation of Latitude computed from Chandler's Formula ("Astronomical Journal," No. 267).

Date.	O.	C.	Date.	O.	C.
1877 Mar. 7	$-0''.02_{215}$	− ·01	1882 Mar. 7	$+0''.08_{105}$	+ ·22
June 6	$+0''.10_{354}$	+ ·21	June 6	$+0''.01_{410}$	+ ·04
Sept. 5	$-0''.13_{158}$	+ ·09	Sept. 5	$0''.00_{429}$	− ·19
Dec. 5	$+0''.02_{303}$	− ·17	Dec. 5	$-0''.03_{349}$	− ·14
1878 Mar. 7	$+0''.01_{315}$	− ·15	1883 Mar. 7	$+0''.05_{357}$	+ ·11
June 6	$+0''.04_{383}$	+ ·11	June 6	$+0''.09_{375}$	+ ·20
Sept 5	$+0''.10_{186}$	+ ·20	Sept. 5	$+0''.01_{572}$	0·00
Dec. 5	$+0''.08_{280}$	·00	Dec. 5	$+0''.13_{339}$	− ·20
1879 Mar. 7	$+0''.04_{263}$	− ·22	1884 Mar. 7	$+0''.01_{287}$	− ·07
June 6	$+0''.03_{385}$	+ ·09	June 6	$-0''.10_{401}$	+ ·15
Sept. 5	$+0''.01_{519}$	+ ·17	Sept. 5	$+0''.07_{571}$	+ ·18
Dec. 5	$+0''.03_{311}$	+ ·15	Dec. 5	$+0''.05_{332}$	− ·06
1880 Mar. 7	$-0''.05_{335}$	+ ·09	1885 Mar. 7	$-0''.09_{341}$	− ·22
June 6	$-0''.08_{401}$	−0·22	June 6	$-0''.03_{114}$	− ·07
Sept. 5	$-0''.14_{535}$	0·00	Sept. 5	$-0''.08_{498}$	+ ·19
Dec. 5	$-0''.04_{409}$	+ ·21	Dec. 5	$-0''.06_{310}$	+ ·13
1881 Mar. 7	$+0''.07_{328}$	+ ·11	1886 Mar. 7	$+0''.03_{336}$	− ·11
June 6	$+0''.05_{359}$	− ·15	June 6	$-0''.05_{377}$	− ·20
Sept. 5	$-0''.13_{171}$	− ·20	Sept. 5	$-0''.06_{530}$	·00
Dec. 5	$-0''.06_{390}$	+ ·04	Dec. 5	$-0''.03_{116}$	+ ·19

This comparison is professedly only rough; but, as it is distinctly favourable to the existence of an inequality such as that of Mr. Chandler's (more especially noticeable when the results are represented in diagrammatic form), a more direct investigation was at once undertaken. A complete examination of all the stars would have involved much labour, and it was, therefore, determined to make some preliminary calculations before definitely embarking on this enterprise.

I. From the theoretical expressions given in Mr. Chandler's paper, above quoted, the epochs of maximum and minimum latitude were calculated. Now, it has long been recognised that there are systematic errors of *annual* period affecting the Greenwich N.P.D.s, the origin of which is not yet completely understood, but which it is necessary to eliminate carefully for the purposes of the present discussion. This can be done by comparing observations of the same star made (say) in 1880

December and 1883 December, when the phase of the annual inequality should be the same, but that of Mr. Chandler's inequality should be a maximum in one case and a minimum in the other. Accordingly search was made for observations of the same stars, in months of the same name, at two epochs when such observations should be in one case on the crest, in the other in the trough of Mr. Chandler's wave, and the mean differences formed, weights being assigned according to the formula $\frac{2mn}{m+n}$, where m and n are the numbers of observations at the two epochs. The results, with corresponding weights, are given in Table IV.

The material available must now be restricted to 1880 and following years, for there are systematic corrections to be applied to the individual results in 1877–1879, though these corrections were applied in the Ten-Year Catalogue.

TABLE IV.

Epochs of Maximum.	Minimum.	Diff.	Weight.
1883 May 20	1880 May 23	−0·62	51
1880 Dec. 26	1883 Dec. 19	−0·05	48
1884 July 27	1881 July 31	−0·69	39
1882 Mar. 3	1885 Mar. 4	−0·27	230
1885 Oct. 11	1882 Oct. 8	−0·18	87
1883 May 20	1886 May 19	−0·44	120
1886 Dec. 28	1883 Dec. 19	−0·60	38
1884 July 27	1887 Aug. 8	−0·82	76
1888 Mar. 10	1885 Mar. 4	+0·16	60
1885 Oct. 11	1888 Oct. 29	−0·46	89
1889 June 12	1886 May 19	−0·20	122
1886 Dec. 28	1890 Jan. 21	−0·40	79
	Mean ...	−0·35	

The sign − implies that the differences of the observed N.P.D.s are too large, or, according to Chandler, that at the period of maximum the mean colatitude is too large, and at the period of minimum the mean colatitude is too small.

II. So far the theoretical difference between the epochs of maximum and minimum is very fairly confirmed, though it is obvious that there are large accidental errors. As a further and independent test, the epochs were selected where the wave crosses the zero line; but there are of course ascending nodes and descending nodes, and comparisons were made between nodes of opposite senses, and not those of the same sense. The

results, as will be seen from Table V., were not so favourable to the theory, which may be due to one of three causes—

(1) The large accidental errors, in which are to be included systematic errors of a different kind from the one here considered. It will be shown, for instance, in the sequel that there is evidence of a 5-yearly inequality.

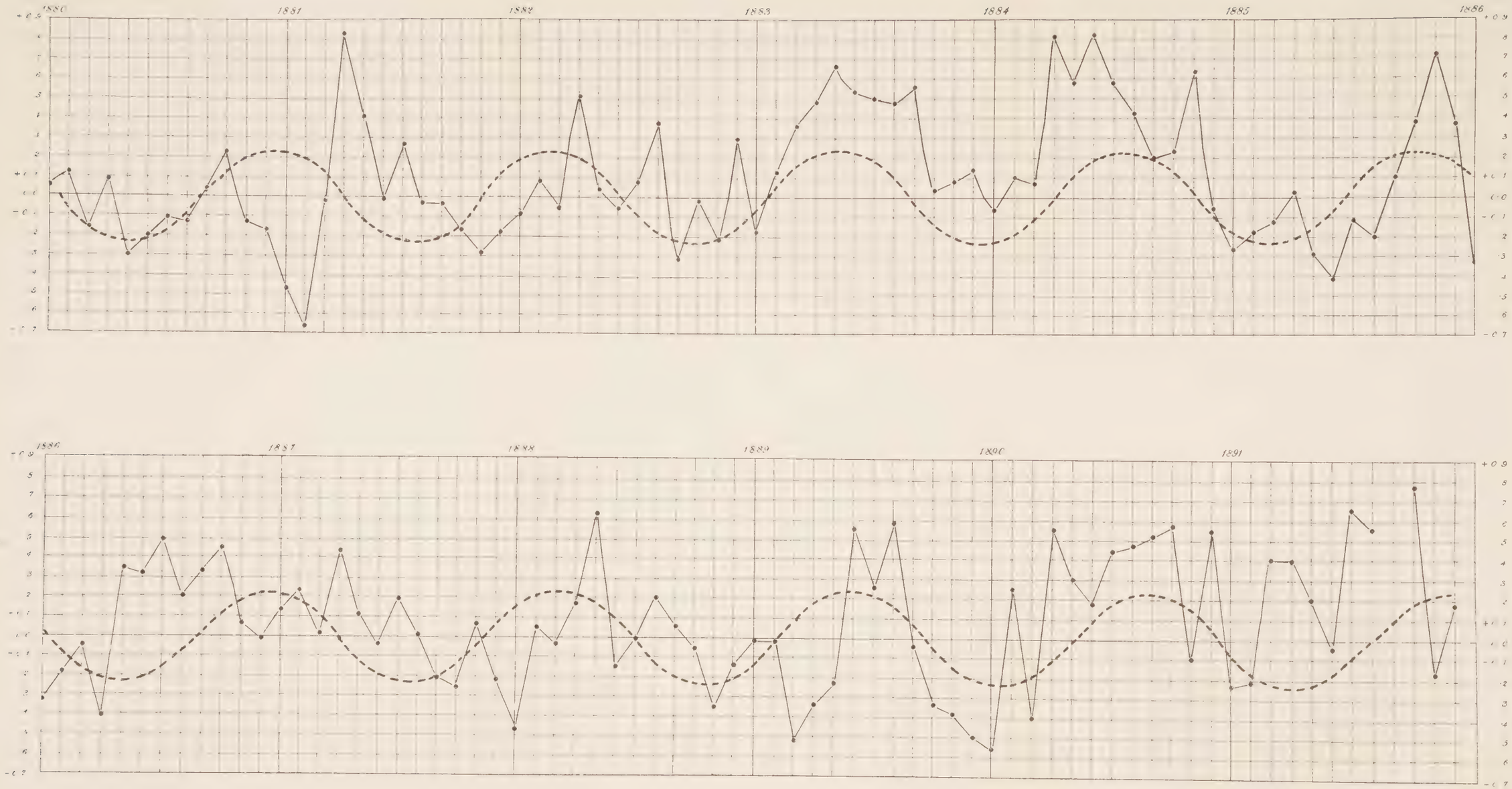
(2) A slight error in the epoch of the inequality, owing to which the wave is displaced in the direction of its length. The results of Table IV. would in this case not be appreciably affected; but there would be the maximum disturbance of Table V. It would appear from the sequel that the error, if any, is small.

(3) A want of symmetry in the wave, owing to the rotation of the pole being elliptic and not circular. It is evident from the sequel that this is very doubtful, but combined with (1) might be the explanation of the persistence of sign in Table V.

TABLE V.

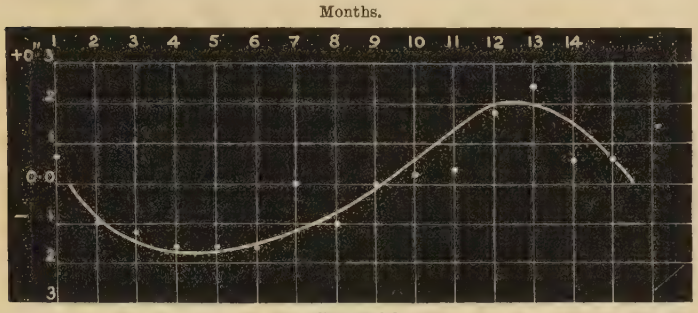
Epochs of Zero.	Zero.	Diff.	Weight.
1883 Sept. 5	1880 Sept. 9	−0″.74	106
1881 April 14	1884 April 8	−0.13	120
1884 Nov. 14	1881 Nov. 16	−0.16	74
1882 June 21	1885 June 24	−0.11	127
1886 Jan. 29	1883 Jan. 28	+0.24	101
1883 Sept. 5	1886 Sept. 8	−0.07	168
1887 April 19	1884 April 8	+0.06	99
1884 Nov. 14	1887 Nov. 25	−0.26	138
1888 July 5	1885 June 24	−0.15	85
1886 Jan. 29	1889 Feb. 19	+0.29	53
1889 Oct. 1	1886 Sept. 8	−0.22	114
	Mean ...	−0.14	

III. The most satisfactory material for such a discussion as the present is obviously the series of observations of the close circumpolars, and especially *Polaris*, which extend over many months, and are otherwise numerous, and were accordingly excluded from discussions I. and II., to be treated independently. A treatment of these precisely similar to that in discussions I. and II. need not be further considered here, as it is virtually included in the final discussion; wherein monthly means uncorrected for R − D were formed from the observations of these stars in the years 1880–1891, and compared with an adopted mean place for 1885·0, obtained by combining the places in the Ten-Year Catalogue 1880·0 and the Five-Year Catalogue 1890·0 (shortly to be published), and the differences plotted on paper as



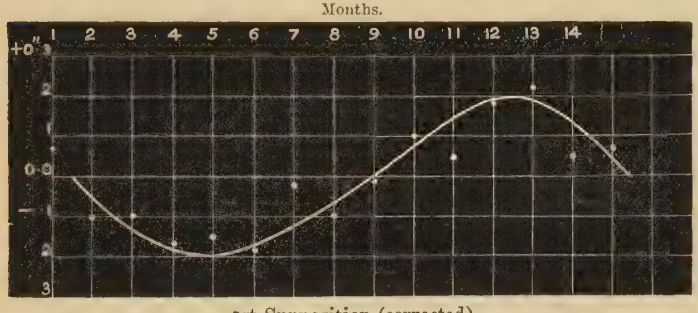
Monthly differences of the four circumpolar stars reduced to epoch 1885. _____
Chandler's Curve. - - - - - -

in Plate I, on which is also shown Mr. Chandler's theoretical curve. It will be seen that there is a fair agreement



1st Supposition.

almost throughout, although there are three marked divergences between the two which do not seem to be wholly explicable by



1st Supposition (corrected).

accidental error. These occur about 1881, 1886, and 1891, and the equality of the intervals separating them suggests a five-yearly disturbance, as mentioned above, though the evidence is, of course, very incomplete.

But when corresponding phases of the wave are taken together and the mean result formed for the whole of the nine periods, there seems to be indisputable evidence of the Chandler wave. There is a little doubt occasionally as to the assignment of particular months which fall between two of the fourteen or fifteen phases of the wave; but, adopting the two different suppositions of a fourteen- or fifteen-month period as roughly agreeing with the varying periods of rotation at the beginning of 1880 and end of 1890 respectively, the observations give the results shown in Table VI.

The results of columns 2 and 4 have been corrected for the general mean correction +0″·12.

The 3rd and 5th columns have been corrected as follows:— It has been assumed that the R – D correction varies annually

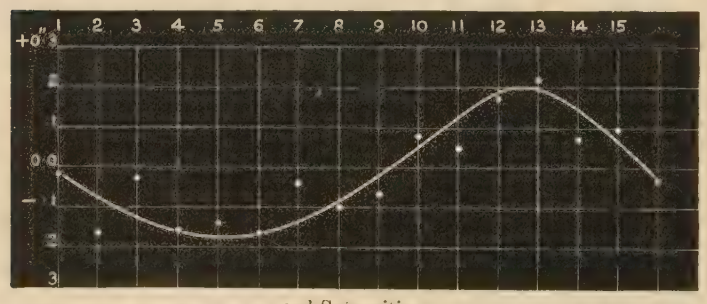
about a constant mean value during the period under discussion, and that the mean for the four polars above and below pole is $-0''\cdot35$. The value of the correction for the different months has been computed from the coefficients given by Mr. Turner in his paper communicated to the Society in March last, and the following corrections for the differences between these values and the mean have been applied.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
$+''\cdot05$	$+''\cdot07$	$+''\cdot01$	$-''\cdot06$	$-''\cdot15$	$-''\cdot14$	$-''\cdot10$	$-''\cdot05$	$-''\cdot01$	$-''\cdot02$	$+''\cdot02$	$+''\cdot03$

The general mean correction of $+0''\cdot09$ has also been applied. The wave form given by the corrected results appears to be the more symmetrical.

TABLE VI.

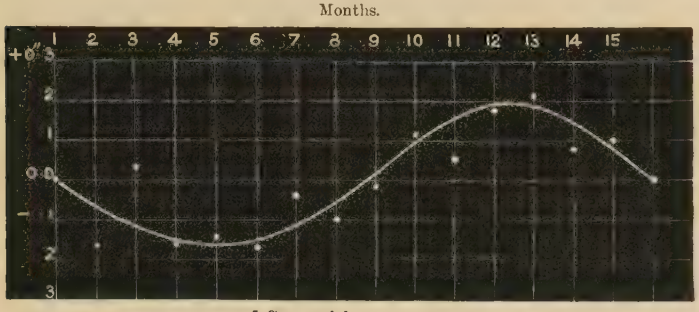
Phase.	1st Supposition.	1st Supposition. Corrected for R−D.	2nd Supposition.	2nd Supposition. Corrected for R−D.
	$''$	$''$	$''$	$''$
1st month	$+0\cdot07_{246}$	$+0\cdot09$	$-0\cdot01_{229}$	$0\cdot00$
2nd ,,	$-0\cdot10_{221}$	$-0\cdot10$	$-0\cdot17_{218}$	$-0\cdot16$
3rd ,,	$-0\cdot11_{254}$	$-0\cdot10$	$-0\cdot02_{171}$	$+0\cdot03$
4th ,,	$-0\cdot16_{253}$	$-0\cdot17$	$-0\cdot15_{245}$	$-0\cdot16$
5th ,,	$-0\cdot15_{225}$	$-0\cdot14$	$-0\cdot13_{229}$	$-0\cdot14$
6th ,,	$-0\cdot15_{232}$	$-0\cdot18$	$-0\cdot16_{224}$	$-0\cdot16$
7th ,,	$0\cdot00_{233}$	$-0\cdot02$	$-0\cdot04_{215}$	$-0\cdot03$
8th ,,	$-0\cdot10_{217}$	$-0\cdot10$	$-0\cdot10_{217}$	$-0\cdot10$
9th ,,	$0\cdot00_{221}$	$-0\cdot01$	$-0\cdot07_{221}$	$-0\cdot01$
10th ,,	$+0\cdot02_{217}$	$+0\cdot10$	$+0\cdot09_{217}$	$+0\cdot11$
11th ,,	$+0\cdot04_{198}$	$+0\cdot05$	$+0\cdot05_{185}$	$+0\cdot07$
12th ,,	$+0\cdot19_{270}$	$+0\cdot19$	$+0\cdot19_{276}$	$+0\cdot18$
13th ,,	$+0\cdot26_{234}$	$+0\cdot23$	$+0\cdot21_{213}$	$+0\cdot21$
14th ,,	$+0\cdot07_{276}$	$+0\cdot06$	$+0\cdot09_{211}$	$+0\cdot09$
15th ,,	...	...	$+0\cdot10_{216}$	$+0\cdot10$



2nd Supposition.

The 2nd supposition especially, and to some extent the 1st, shows something of a want of symmetry in the wave, which

is more or less removed by the application of the correction for an assumed monthly difference in the R−D correction, and



2nd Supposition (corrected).

further evidence is needed to confirm this. The investigation will be continued, and the present paper must be regarded as preliminary merely; but the matter is of sufficient importance to make it advisable to publish these results at once.

On the Systematic Errors of the Moon in Right Ascension.
By H. H. Turner, M.A., B.Sc.

In February 1892 Captain Grant, of the Ordnance Survey, consulted the Astronomer Royal concerning operations for fixing the boundary of Mashonaland, in concert with Portuguese officers, by parallels of latitude and longitude.

It was decided that he should determine the requisite longitudes by Moon-culminations, taking with him a portable transit by Troughton & Simms. Application has several times been made to the Astronomer Royal, in connection with similar operations, for a list of the Moon's errors on certain dates, as determined by the Greenwich Transit Circle, but in the present instance the actual landmarks were to be fixed on the spot, and hence retrospective corrections depending on information supplied from Greenwich were out of the question. It remained to be decided whether from recent observations any prospective corrections to the Moon's place could be tabulated and furnished to Captain Grant before his departure. For this purpose a complete list of observed errors of the Moon in R.A. for the years 1883–1891 was formed. The year 1883 was the first in which Newcomb's corrections to Hansen's tables were applied in the *Nautical Almanac*; and quite apart from any theoretical question as to the exact relation of these corrections to Hansen's tables, their adoption in the *Nautical Almanac* has had the advantage of bringing readily into prominence several features of the residuals previously masked by the large corrections which had been

required by those tables. As an example, I may quote the annual mean error in R.A. of the Moon, given in the annual reports of the Astronomer Royal to the Society, or to the Board of Visitors. The latter value, computed in May, which sometimes differs slightly from the former, computed in February, is to be preferred; for by May the observations of the previous year have been examined more thoroughly, and numerical errors, if any, corrected. The following is a list of such annual means:—

	Report to R.A.S.	Report to B. of V.		Report to R.A.S.	Report to B. of V.
	s	s		s	s
1883	+0·032	+0·031	1888	+0·079	+0·090
1884	+0·021	+0·018	1889	+0·010	+0·010
1885	+0·028	+0·024	1890	+0·020	+0·020
1886	+0·029	+0·029	1891	+0·079	+0·077
1887	+0·068	+0·059	Mean	+0·041	+0·040

The persistently positive sign of this quantity is noteworthy; and it is quite possible that the departures from the mean value may be accidental.

Again, there is a persistent difference, as will appear presently, between the errors before and after Full Moon, which may apparently be predicted empirically without making any attempt to refer it to one of several possible causes.

The aforesaid errors for 1883–1891 were arranged so that corresponding lunations in each year (the correspondence being, of course, only approximate) and corresponding days in each lunation (reckoning from Full Moon) were taken together. There were naturally many gaps in each lunation—days on which no meridian observation had been obtained at Greenwich—but from the data available an attempt was made to estimate the mean error on five dates in each lunation—viz. nine days before Full Moon, five days before, Full Moon, five days after, and nine days after. This was done for the mean January lunation, the mean February lunation, &c.; that is all the lunations where the Full Moon fell in January were considered "corresponding" and taken together, as remarked above; and if there had been an observation on every day, we should have had forty-five errors of which to take the mean to obtain the mean error at Full Moon in January—viz. a set of five days in each year comprising Full Moon and two days each side; and similarly for the other epochs. As a matter of fact, instead of forty-five errors there were generally only about fifteen, and hence came considerable uncertainty in estimating correctly.

The first point noticed from the results of this work was that the errors after the Full were algebraically greater than those

before. Further, that this difference was more marked in the summer than in the winter months. By a graphical process the following mean differences were deduced between the errors before and after Full, a positive sign indicating that the error after the Full is greater than that before:—

	s		s
Jan.	+0·04	July	+0·17
Feb.	+0·11	Aug.	+0·13
Mar.	+0·16	Sept.	+0·07
Apr.	+0·20	Oct.	+0·01
May	+0·21	Nov.	−0·02
June	+0·20	Dec.	+0·02

The change at Full has been treated for simplicity as a discontinuity and not as a progressive change. The whole process being, in fact, of a tentative character, it is not advisable to give figures in greater detail; but it may be remarked that the adoption of an erroneous semi-diameter is a possible explanation of this phenomenon; for errors after the Full are deduced from observations of the second limb only, and before from those of the first. Now, if the adopted semi-diameter is too large, too large a quantity will be subtracted from transits after the Full; the observed "transit of centre" will be too small, and the error of the tables consequently a positive quantity; while before the Full the reverse is the case. Again, the adopted semi-diameter may be large owing to the spurious border, due to irradiation, which surrounds the limb of the Moon, and has been recognised as explaining "projection" in occultations of bright stars, and which would be most emphatic at midnight, the time of transit of Full Moon, when the diameter is usually measured with meridian instruments; whereas at the transits of First and Last Quarter Moons the irradiation border would be lost in the twilight background; and this would be especially the case in the summer. If this explanation be the true one, then the use of errors obtained by a large instrument for correction of those with a small is of somewhat doubtful expediency.

Next it was noticed that, considering the mean errors on any given date (nine days before Full, five days before, &c.) in, say, a January lunation, there was a certain progression from year to year; and it was hoped that by plotting these errors as ordinates against the years as abscissæ, a curve might be obtained sufficiently definite to allow of extension for one year, and hence the approximate error on this date for January 1893, &c. might be predicted. The great drawback to the method is the number of gaps in the different series; and as a first attempt two or three years were taken together to remedy this defect. The

resulting predictions for January and February 1893 were compared with the actual observations which were already available, and it was seen that no great measure of success had been attained. A second attempt was then made by first filling up the gaps by estimation from neighbouring dates, and the results of this attempt were more satisfactory, and were adopted for use.

Since the subjoined table was furnished to Captain Grant, the Moon has now been observed throughout the period under consideration, and it may, therefore, interest the Fellows of the Society to note the measure of success attained by a purely empirical method in a case of this kind. From what has been said above, it will be clear that this note is in no way intended as a serious contribution to lunar theory.

It will be seen that predictions were not made for the earlier days in each lunation, though the observations with the Transit Circle are printed.

Corrections to R.A. of Moon in 1892. *Predicted approximately from the errors* 1883—1891 *in Transit Circle Observations at Royal Observatory, Greenwich.*

	Pred.	Obs.	O−P
	s	s	s
May 3	+0·14	...	...
4	+0·12	...	...
5	+0·11	...	...
6	+0·09	+0·15	+0·06
7	+0·08	...	...
8	+0·07	−0·05	−0·12
9	+0·05	+0·16	+0·11
10	+0·03	+0·10	+0·07
11	0·00	−0·09	−0·09
12	−0·04	−0·10	−0·06
13	−0·10	...	...
14	−0·15	−0·02	+0·13
15	−0·19	−0·20	−0·01
16	−0·23	...	...
17	−0·27	...	...
18	−0·30	−0·13	+0·17
Numerical Sum ...		1·00	0·82

	Pred.	Obs.	O−P
	s	s	s
May 30	...	−0·08	...
June 1	...	+0·07	...
2	...	+0·07	...
3	+0·19	...	...
4	+0·16	...	...
5	+0·09	−0·01	−0·10
6	+0·02	...	...
7	−0·05	−0·04	+0·01
8	−0·08	−0·11	−0·03
9	−0·10	−0·06	+0·04
10	−0·13	−0·02	+0·11
11	−0·17	...	...
12	−0·21	−0·25	−0·04
13	−0·25	...	...
14	−0·28	...	...
15	−0·31	...	...
16	−0·33	...	...
17	−0·35	−0·40	−0·05
Numerical Sum	...	0·89	0·38

	Pred.	Obs.	O−P
	s	s	s
July 2	+0·12	+0·11	−0·01
3	+0·07	−0·04	−0·11
4	+0·01	+0·02	+0·01
5	−0·04	...	...
6	−0·09	...	...
7	−0·12	+0·09	+0·21
8	−0·13	−0·03	+0·10
9	−0·15	−0·21	−0·06
10	−0·19	−0·36	−0·17
11	−0·24	...	...
12	−0·28	...	...
13	−0·29	...	...
14	−0·29	...	...
15	−0·30	...	...
16	−0·30	...	...
Numerical Sum	...	0·86	0·67

	Pred.	Obs.	O−P
	s	s	s
July 28	...	+0·14	...
29	...	+0·10	...
30	...	+0·11	...
31	+0·10	...	...
Aug. 1	+0·06	...	...
2	+0·01	...	...
3	−0·04	...	...
4	−0·08	+0·17	+0·25
5	−0·11	...	...
6	−0·13	+0·11	+0·24
7	−0·15	...	...
8	−0·15	...	...
9	−0·16	...	...
10	−0·16	−0·52	−0·36
11	−0·17	−0·40	−0·23
12	−0·17	−0·41	−0·24
13	−0·18	−0·49	−0·31
14	−0·18	−0·46	−0·28
15	−0·17	−0·42	−0·25
16	...	−0·39	...
	Numerical Sum ...	2·98	2·16

	Pred.	Obs.	O−P
	s	s	s
Aug. 26	+	+0·17	...
27	...	...	...
28	...	+0·14	...
29	...	...	...
30	+0·16	+0·21	+0·05
31	+0·16	...	...
Sept. 1	+0·14	−0·06	−0·20
2	+0·12	...	...
3	+0·09	+0·16	+0·07
4	+0·04	−0·13	−0·17
5	−0·02	−0·19	−0·17
6	−0·06	−0·22	−0·16
7	−0·10	−0·26	−0·16
8	−0·13	−0·37	−0·24
9	−0·16	...	...
10	−0·16	−0·38	−0·22
11	−0·15	−0·38	−0·23
12	−0·14	...	...
13	...	−0·45	...
	Numerical Sum ...	2·36	1·07

Corrections to Hansen's Tables de la Lune. By James Gordon.

(*Communicated by the Rev. S. J. Johnson, M.A.*)

I have reviewed Professor Newcomb's "Researches on the Motion of the Moon," part 1, and I have accepted his graphical interpolation of the individual corrections to the Moon's mean longitude for intervals of a quarter of a century. I then throughout gave each equation of condition the weight of unity, as I look with suspicion on assigning different weights to the observations. I took out from the theory all of Hansen's terms of long period due to the action of the planets on the Moon, and substituted an inequality of long period, which goes through precisely the same changes in 2831 years, and is made up of the two composite periods of $257\frac{4}{11}$ years and 149 years respectively. This inequality depends upon the distance of the Moon from the plane of the Sun's equator, when the Moon arrives at conjunction with the Sun. The following is the correction to the Moon's mean longitude which I have determined :—

$$\delta\epsilon = \delta v + \delta nz.$$

In which

$$\delta v = +0''{\cdot}23 - 29''{\cdot}35\ \mathrm{T} - 3{\cdot}976\ \mathrm{T}^2.$$

And

$$\delta nz = -(\mathrm{V}_1 + \mathrm{V}_2 + \mathrm{M}) + (14''{\cdot}1 \sin \mathrm{A} + 0''{\cdot}9 \sin \mathrm{A}')$$

in which T is the number of centuries from the epoch of Hansen's Tables, viz. : January 0·0 1800; δv is the correction to the Moon's true longitude, and δnz to that of the fundamental argument. The terms V_1, V_2, and M are the values assigned by Hansen in the respective tables, xlii., xli., and xl., with the arguments 31, 30, and 29. The outstanding residuals are as follows :—

1625	+2″·1	1725	−1″·4	1825	−0″·2
1650	−2·4	1750	−1·4	1850	+0·8
1675	−0·4	1775	+1·0	1875	−0·5
1700	+0·1	1800	+0·7		

I have calculated a table at five-years intervals between A D 1600 and A D 2000 inclusive; of the values of $\delta\epsilon$, which represents the correction to the Moon's mean longitude; and it is a well-known fact that Hansen, being unable to determine the coefficients of his *Venus* terms, from theory, assigned such values to them as brought observation and theory into agreement during the period 1750–1850, but this he only attained by sacrificing accuracy before and after this interval. Now, if my corrections to the Moon's mean longitude are well founded, they ought to

approach zero during the above interval. The following table gives the correction $\delta\epsilon$ for the interval 1750–1850:—

Epoch.	Corr.	Epoch.	Corr.	Epoch.	Corr.
1750	+1″·5	1785	−0″·9	1820	+0″·3
1755	+1·1	1790	−1·3	1825	0·0
1760	0·0	1795	−1·3	1830	+0·5
1765	−0·7	1800	−0·5	1835	+0·6
1770	−0·5	1805	−0·6	1840	0·0
1775	−1·0	1810	−0·6	1845	−0·2
1780	−1·8	1815	−0·1	1850	−0·4

I then made a selection of 105 of the best of the equations of condition formed from the occultation of stars given in Professor Newcomb's "Researches on the Motion of the Moon." The terms, however, of $\frac{d\mathrm{D}}{de}\,\delta\epsilon + \frac{d\mathrm{D}}{db_0}\,\delta b_0 = a$ became known by substituting the value for $\delta\epsilon$ as taken from my table, and for δb_0 I took the mean constant value $= +\ 1''\cdot76$ as found for it by Professor Newcomb (see the "Researches," part 1, page 235); this enabled me to bring the equations of condition to the form—

$$\frac{d\mathrm{D}}{ed\varpi}\,e\delta\varpi + \frac{d\mathrm{D}}{id\theta}\,i\delta\theta + \frac{d\mathrm{D}}{d\pi}\,\delta\pi = s' - \mathrm{D} - a.$$

And these I reduced down by least squares in a single group, the resulting normal equations coming out to be as follows:—

$$\begin{aligned} &+3\cdot56\ e\delta\varpi - 0\cdot14\ i\delta\theta - 0\cdot79\ \delta\pi = -1''\cdot88 \\ &-0\cdot14 \quad +0\cdot07 \quad +0\cdot03 \quad = +0\cdot45 \\ &-0\cdot79 \quad +0\cdot03 \quad +0\cdot53 \quad = +0\cdot42 \end{aligned}$$

the solution of which gives

$$e\delta\varpi = -0''\cdot3$$
$$i\delta\theta = +5''\cdot83$$

and

$$\delta\pi = \quad 0\cdot0$$

As $e = 0\cdot055$, and $i = 0\cdot0898$, we have for the middle epoch through which the equations extend, viz. A D 1711·6

$$\delta\varpi = -\ 5''\cdot4 = \text{Correction to the longitude of perigee.}$$
$$\delta\theta = +64\cdot9 = \quad ,, \quad ,, \quad ,, \text{ node.}$$

While $\delta\pi$, the correction to the Moon's parallax, is zero, or, in other words, Hansen's tables require no correction for this element.

Now, in Professor Newcomb's "Investigation of Corrections to Hansen's Tables de la Lune," 1876, he gives for—

$$1861 \qquad \delta\varpi = +2''.2$$

and

$$1868 \qquad \delta\theta = +4''.5$$

Comparing this with my own determination, I have arrived at the following corrections to the motions of the perigee and node, in which T represents as before the number of centuries from the epoch 1800 :—

$$\delta\varpi = -\ 0''.9 \ +\ 5''.09\ T$$

and

$$\delta\theta = +30''.75 - 38''.6\ \ T$$

I have confined myself entirely to modern observations, as the problem of the secular acceleration of the Moon's mean motion is in a very unsettled state. What is aimed at by astronomers is to obtain a constant coefficient progressing according to the square of the time, and this they will never obtain for any great length of time, as the very causes which give rise to this acceleration are not of a constant nature.

Aberlemno, Forfarshire :
1892 *August* 30.

On the Best Form of Mounting for a Large Reflector.

By A. A. Common, LL.D., F.R.S.

A silver on glass mirror of eight or nine feet aperture seems now to be possible, and it becomes worth while to consider the best way to mount such a mirror for astronomical purposes.

Opinions will differ as to the optical arrangements most suitable, but the Newtonian form seems, in my opinion, to be the best, for many reasons that it is not necessary to go into now.

The best use of such an enormous telescope would probably be to explore and discover, and this would naturally be best done by using it as a visual telescope, for which purpose a focal length of about twelve times the aperture would perhaps be most suitable, giving for the smaller mirror above mentioned some ninety-six feet focal length.

To mount such a telescope equatorially and put a dome over it in the usual way would be a most costly undertaking, and even if the money were available it is very doubtful if any form of equatoreal would be the most suitable. The difficulty of providing access to the eye end for the observer, and of following the movement, especially when we remember that off the

meridian the upper part of the tube must be rotated, is one not easily got over.

The equatorial movement is necessary for photographic and spectroscopic work, but here a very much shorter focal length can be advantageously used. For visual work it is undoubtedly the best, but it may be obtained at such a sacrifice of advantages that could otherwise be obtained, that it might be worth while giving up the one for the others.

The chief consideration in designing a mounting for such an immense telescope would be to keep the cost as low as possible ; the first thing, therefore, is to give up the equatorial mounting, with its expensive and heavy work, and adopt some kind of altazimuth mounting. We have had large reflectors mounted in this manner. The plan used by Sir William Herschel in mounting his four-foot is typical. For the work of exploration it answers admirably, and the observer is provided with a fairly safe position. There are, however, many objections, such as the close tube, the absence of protection from the wind and rain, and the want of perfect protection and comfort for the observer. Keeping in mind the requirements that experience has shown to be important in designing a reflecting telescope, particularly the use of a skeleton tube instead of a close one, easy access to the mirror for covering or removal, movement in one plane only, &c., and endeavouring to get the very best possible conditions for the observer, I have been led to devise a form of mounting that does certainly offer every advantage that I could wish, excepting that of equatorial motion. The facilities for movement in both directions are so great that I have not any doubt that an apparatus could be designed that would work well enough to keep the object under examination in the field of view in a sufficiently steady manner.

I would take as a basis for the mounting of the telescope that form designed by the late Dr. Draper, and described by him in his paper "On the Construction and Use of a Silvered Glass Telescope," published by the Smithsonian Institution. (The earliest account of a mounting on this principle that I know is in Smyth's *Celestial Cycle*, vol. ii., page 540; this is Miss Herschel's telescope, made probably by Sir William Herschel.) This form of mounting is, no doubt, so well known that it is hardly necessary to do more than mention that the telescope is hung by one end on trunnions, the eye end being in one of them, which is made hollow for the purpose. The counterpoising of the free end of tube with mirror attached is effected by weights carried at the ends of rods supported at their lower ends and connected with the tube by iron wire ropes. The square framework carrying the tube and counterpoises revolves on a central pin, so the eye end is carried round in a circle of about the diameter of the focal length. I would use such a framework as this, but double the length, with the telescope in one half and the counterpoise weights in the other. The centre

of motion I would place exactly under and midway between the trunnions, the eye-piece end being about five feet from the centre of motion, causing a necessary movement of the observer of at the most 30 inches per hour.

Instead of a tube connecting the mirrors it would only be necessary to have two lattice girders braced together at the top and bottom. For a few feet near the trunnions a tube would be needed, but instead of putting any more tube I would enclose the framework containing the mirrors entirely, making it a large dark chamber, the connection being made at the trunnion end by a flexible material.

The square framework carrying the dark chamber which forms the telescope and the counterpoise weights in the other side would rotate on a central vertical pin, the greater part of the weight being taken off by floating a suitable circular tank in water; the mirror end of the two lattice girders could slide along an arc of a circle, so that by suitable gearing an end movement could be given in altitude, a similar movement in azimuth being obtained at the edge of the circular tank. We should thus have a complete telescope capable of being pointed to any part of the heavens.

To shelter this from the wind and weather, and to support the observer, I would enclose the whole in a framework covered with any suitable material, and of such a shape as to come close up to the upper end of the tube near the trunnions, where the chamber in which the observer could sit, would be placed. The whole of this outer framework would run on a circular railway, and could be made sufficiently wide to provide for two or three hours' continuous movement of the contained telescope without any alterations, the only opening being a flap shutter at an angle of 45°, covering the open end of the telescope when not in use.

Access would be obtained for the observers by suitable stairs on the outer framework, which, being entirely detached from the inner telescope, would not affect it.

There are many matters of detail which would have to be worked out, but it will be found that the form of mounting I have indicated here is one that offers many advantages, particularly as regards the question of cost, while it provides for the safety and comfort of the observer absolutely.

There are two modifications in this form that are worth consideration—the first, that the second part of the frame carrying the counterpoise weights in the above-mentioned plan might be dispensed with, as well as the covering of inner framework, counterpoising it by weights in the floating tank. This would reduce by nearly one-half the size of the outer covering, but it would be attended with this disadvantage: the wind would have enormous power in the outer covering, as the centre of rotation would be near one end. The other modification is to have the framework containing the telescope rotating exactly on the same plan as Dr. Draper's, and enclose the whole in a fixed circular house

similar to his, with a provision for carrying the observer similar in general character to his, making it, in fact, exactly on the lines he has laid down.

The first modification would, perhaps, be the best form altogether, as the sides and ends of the outer house could be made with a considerable slope, so as to reduce the upsetting power of the wind. This would retain the important position of the observer as close as possible to the centre of motion of the telescope.

Probable Error of the Clock Correction when both the Clock Rate and the Instrumental Constants are found by a Least Squares Solution of a Single Night's Observations. By the Rev. John T. Hedrick, S.J.

(*Communicated by the Rev. W. Sidgreaves, S.J.*)

It seems to be a common practice in the comparison of time determinations, as in longitude work, to give a constant probable error for the clock correction of each night and to combine the different nights' work according to these probable errors. This is equivalent to taking the clock rate as known perfectly, whereas its value has also its degree of uncertainty, making the probable error of the clock correction quite different for different moments. Of course, if the time comparison takes place during the period of observation, and especially if about its middle, there will be less objection to the method.

A reason for this neglect of the probable error of the clock rate may be the difficulty of determining it when another quite common practice is followed of determining the clock rate from the comparison of the clock corrections found from night to night. If results are expected of sufficient accuracy to make it worth while taking account of probable errors, this practice seems hardly defensible for observations made with portable instruments. For we are likely to have periodic or irregular fluctuations of rate in a clock, not of the best, exposed to receiving injurious shocks in carriage, and not set up so as to be thoroughly protected against the effects of change of temperature, or even against instability in the clock pier. Whatever periodic or accidental errors may exist in the star places of the various modern ephemerides, they are so small that, except in a fixed observatory, the proper method is to find the clock rate each night from that night's observations.

Supposing that a least squares solution of the night's work is thought worth the while, there is still a difficulty in getting *the general expression for the probable error of the clock correction at any moment.* Its probable error at a given moment may be found by making this moment the epoch of the constant part of the total clock correction; but this may bring in practical diffi-

culties in computing, requiring, for example, the use of more decimal places in the coefficients and logarithms.

Let

ΔT be the clock correction at any moment,
ΔT_0 the clock correction at some assumed moment, and
ρ the clock rate.

From the sum of the squares of the residuals after substitution in the equations of condition of the values found by the least squares solution and the coefficients occurring in the solution, we can find the probable error of ΔT_0 and ρ. The probable error of ΔT will be a function of these probable errors and the interval between the epochs of ΔT and ΔT_0, but it will not be a function of these only, if the proper epoch is not chosen for ΔT_0; for in this case the probable error of ΔT_0 will itself depend on that of the rate. (See equations (2) and (3), below.)

Let

$$n', n'', n''' \ldots .$$

be the known terms of the equations of condition after reduction to weight 1 . ΔT_0 and ρ are each determined as a linear function of the ns.

Let

$$\Delta T_0 = \alpha' n' + \alpha'' n'' + \alpha''' n''' + \ldots .$$
$$\rho = \beta' n' + \beta'' n'' + \beta''' n''' + \ldots .$$

where α', β', &c., are functions of the constant coefficients of the equations of condition.

Now

$$\Delta T = \Delta T_0 + t \,.\, \rho,$$

where t is the interval between the epochs of ΔT and ΔT_0.

Hence

$$\Delta T = (\alpha' + \beta' \,.\, t)n' + (\alpha'' + \beta'' \,.\, t)n'' + (\alpha''' + \beta''' \,.\, t)n''' + \ldots .$$

Let p be the probable error of an observation of weight 1, and $p\Delta T$, $p\Delta T_0$, and $p\rho$ the probable errors of these quantities. We have (Chauvenet, ii., pp. 498, 499, and 516)—

$$(p\Delta T_0)^2 = p^2 \,.\, [\alpha\alpha], \qquad (p\rho)^2 = p^2 \,.\, [\beta\beta],$$
$$(p\Delta T)^2 = p^2 \,.\, [(\alpha + \beta \,.\, t)(\alpha + \beta \,.\, t)] = p^2 \,.\, ([\alpha\alpha] + 2[\alpha\beta] \,.\, t + [\beta\beta] \,.\, t^2).$$

From the degree in t of the parenthesis it is evident that there is a value of t which makes $p\Delta T$ a minimum, and but one value. Let us put $\Delta T_{00} = \Delta T$ for this epoch. It is evident also that if the epoch of ΔT_{00} were chosen as the epoch of ΔT_0, we should have $[\alpha\beta] = 0$; for if it is not zero $p\Delta T$ will not be a

minimum for that epoch. Hence, counting t from the epoch of ΔT_{00}—

$$(p\Delta T)^2 = p^2 . ([\alpha\alpha] + [\beta\beta] . t^2) = (p\Delta T_{00})^2 + (p\rho)^2 . t^2 \quad . \quad . \quad . \quad (1)$$

Hence the probable error of ΔT_{00} is independent of that of the rate. If the epoch assumed for ΔT_0 be not that of ΔT_{00}, and t' be the interval between the two epochs,

$$(p\Delta T_0)^2 = (p\Delta T_{00})^2 + (p\rho)^2 . t'^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and

$$(p\Delta T)^2 = (p\Delta T_0)^2 - (p\rho)^2 . t'^2 + (p\rho)^2 . t^2 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

There is no difficulty in assigning the epoch of ΔT_{00} when only it and ρ enter our equations. It is the mean (simple or weighted) of the times of observation. But we have commonly to determine also the azimuth (a), and in the case of a portable instrument the collimation (c) as well, and perhaps the azimuth after reversal (a'). In this case the epoch of ΔT_{00} is not the mean of the times of observation, and it is the object of this note to show *how to find this epoch from the coefficients formed in solving the normal equations for the epoch of* ΔT_0, or to find the quantity t' of equation (2). The probable error of the clock correction at any moment will then be found by (1) or (3).

Since the squares of the probable errors of the quantities found by a least squares solution are inversely proportional to the coefficients each would have in the final equation if it were the first unknown found, it follows that the moment at which the clock correction has the minimum probable error is the moment which, chosen as the epoch from which to compute the coefficients of the rate in the equations of condition, would bring out ΔT_0 in the final equation with the maximum coefficient.

Let us suppose the most general case, namely, that we have to determine a, a', c, ρ, and ΔT_0, and let w = weight. We have this group of five normal equations, using Gauss's notation.

$$[waa]x + [wab]y + [wac]z + [wad]u + [wae]v + [wan] = 0,$$
$$[wab]x + [wbb]y + [wbc]z + [wbd]u + [wbe]v + [wbn] = 0, \text{ \&c.}$$

Let the order of the unknowns and that of their elimination be that given above.

For $[ee . 4]$, the coefficient of $v(\Delta T_0)$ in the final equation, or the quantity to be made a maximum, we have

$$[ee . 4] = [wee] - \frac{[wae]}{[waa]}[wae] - \frac{[be . 1]}{[bb . 1]}[bc . 1] - \frac{[ce . 2]}{[cc . 2]}[ce . 2] - \frac{[de . 3]}{[dd . 3]}[de . 3].$$

In the second member all the terms except the last are independent of d, the coefficient of the rate, and hence of the epoch of ΔT_0, and all are positive. Hence $[ee . 4]$ will be a maximum when the epoch is so chosen as to make the last term zero, or, since $[dd . 3]$ is not infinite, when $[de . 3] = 0$.

We have the following expressions, in determinant notation*:—

$$[de \,.\, 3] = |[waa][wbb][wcc][wde]| \div |[waa][wbb][wcc]|,$$
$$[ee \,.\, 3] = |[waa][wbb][wcc][wee]| \div |[waa][wbb][wcc]|.$$

Or, since e, the coefficient of ΔT_0 in the equations of condition, $=1$—

$$[de \,.\, 3] = |[waa][wbb]]wcc][wd]| \div |[waa][wbb][wcc]|,$$
$$[ee \,.\, 3] = |[waa][wbb][wcc][w]| \div |[waa][wbb][wcc]|.$$

The only coefficient affected by a change of epoch for ΔT_0 is d, the coefficient of the rate. The denominator of $[de \,.\, 3]$ is independent of d, and, as it is not infinite, to make $[de \,.\, 3] = 0$ its numerator must become zero. This numerator expressed in the fuller determinant form is—

$$\text{No. of } [de \,.\, 3] = \begin{vmatrix} [waa][wab][wac][wad] \\ [wab][wbb][wbc][wbd] \\ [wac][wbc][wcc][wcd] \\ [wa][wb][wc][wd] \end{vmatrix}$$

Let us suppose that we have formed and solved our normal equations with the epoch T for ΔT_0, and let us change the epoch to $T' = T + t'$. The coefficient of the rate is the time of observation minus the epoch of ΔT_0. We shall have the following relations between the two sets of coefficients, d representing in both sets the coefficient of the rate for the epoch T.

Epoch T,	Epoch $T' = T + t'$
d,	$d - t'$,
$[wad]$,	$[wad] - [wa] \,.\, t'$,
$[wbd]$,	$[wbd] - [wb] \,.\, t'$,
$[wcd]$,	$[wcd] - [wc] \,.\, t'$,
$[wd]$,	$[wd] - [w] \,.\, t'$,

* These expressions, as well as those for the other coefficients occurring in the solution of the normal equations (Chauvenet, ii. pp. 531 and 532), can be found by expressing each as a determinant of the second order; *e.g.*

$$[ee \,.\, 3] = \frac{1}{[dd \,.\, 2]} \times \begin{vmatrix} [dd \,.\, 2] & [de \,.\, 2] \\ [de \,.\, 2] & [ee \,.\, 2] \end{vmatrix},$$

substituting in each the determinant expressions for the coefficients of lower order, and applying the theorem

$$\begin{vmatrix} a_{11}a_{21} \end{vmatrix} \begin{vmatrix} a_{11}a_{31} \\ a_{13}a_{33} \end{vmatrix} \begin{vmatrix} a_{11}a_{41} \\ a_{14}a_{44} \end{vmatrix} \begin{vmatrix} \cdots & a_{11} & a_{m1} \\ \cdots & a_{1m} & a_{mm} \end{vmatrix} = a_{11}^{m-2} \cdot |a_{11}a_{22}a_{33} \cdots a_{mm}|.$$

The first member is the determinant whose element in the kth row and lth column is

$$\begin{vmatrix} a_{11} & a_{(k+1)1} \\ a_{1(l+1)} & a_{(k+1)(l+1)} \end{vmatrix}; \quad k, l = 1, 2, 3 \ldots (m-1).$$

Let us substitute the values for the epoch T′ in the numerator of $[de \cdot 3]$. We have

$$\text{No. of } [de \cdot 3] \text{ for epoch T}' = \begin{vmatrix} [waa][wab][wac][wad]-[wa] \cdot t' \\ [wab][wbb][wbc][wbd]-[wb] \cdot t' \\ [wac][wbc][wcc][wcd]-[wc] \cdot t' \\ [wa] \ [wb] \ [wc] \ [wd]-[w] \ \cdot t' \end{vmatrix}.$$

Splitting up this determinant into two and factoring out t' in the second, we have, for the epoch T′—

$$\text{No. of } [de \cdot 3] = |[waa][wbb][wcc][wd]| - |[waa][wbb][wcc][w]| \cdot t'..$$

Putting this equal to zero and noticing that the first term and the factor of t' in the second term are proportional to $[de \cdot 3]$ for the epoch T and $[ee \cdot 3]$ respectively (4), we find for t' *the interval from the epoch assumed for* ΔT_0 *to that which would give the maximum coefficient for* ΔT_0 *in the final equation, or to the epoch at which the clock correction has the minimum probable error,*

$$t' = \frac{[de \cdot 3] \text{ for the assumed epoch}}{[ee \cdot 3]} \quad \ldots\ldots\ldots \quad (5)$$

The value found for t' is the quotient of the same coefficients, after the equations have been freed from all the unknowns except ΔT_0 and ρ, of which it would have been the quotient, had there been only these two unknowns in the original equations, namely, of the coefficient of ΔT_0 in the normal equation in ρ by that in its own normal equation. It will, in general, differ from $[wde] \div [wee]$ = the mean of the times of observation.

In the example given below the square brackets are used also to indicate the number whose logarithm they enclose.

Summary.

The epoch of the clock correction of maximum weight, or minimum probable error, is not, in general, the mean of the times of observation when, besides the constant clock correction and the clock rate, instrumental constants are also determined from the observations, (5).

If these quantities are found by a least squares solution, this epoch is before or after the epoch assumed for the constant clock correction by an interval which is the quotient of the coefficient of the constant clock correction in the normal equation for the rate by its coefficient in its own normal equation, after the elimination of the other unknowns, (5).

If we count from this epoch, the probable error of the clock correction at any other time is what it would be if the constant correction and the rate were independently observed quantities—

that is, its square is the sum of the square of the probable error at this epoch and the product of the square of the probable error of the rate into the square of the interval from this epoch, (1). Hence the square of the probable error of the clock correction at this epoch is equal to the square of the probable error of the clock correction at the assumed epoch minus the product of the square of the probable error of the rate into the square of the interval between the two epochs.

Example.

Number of stars observed, 20. Number of quantities determined, 5.

Putting v here for the residuals, $[vvv] = 0^s{\cdot}0251$.

For an observation of weight 1, $p^2 = 0^s{\cdot}000761 = [6{\cdot}8815]$.

Mean of the times of observation $= 8^h{\cdot}98$. Assumed epoch of $\Delta T_0 = 9^h{\cdot}0$.

$[ee \,.\, 4] = 3{\cdot}28$, $(p\Delta T_0)^2 = [6{\cdot}8815] \div [0{\cdot}5159] = [6{\cdot}3656] = 0^s{\cdot}000232$.

$[dd \,.\, 4] = 4{\cdot}44$, $(p\rho)^2 = [6{\cdot}8815] \div [0{\cdot}6474] = [6{\cdot}2341] = 0^s{\cdot}000171$.

$[de \,.\, 3] = +5{\cdot}75 = [0{\cdot}7597]$, $[ee \,.\, 3] = +6{\cdot}85 = [0{\cdot}8357]$, $t' = [9{\cdot}9240] = 0^h{\cdot}84$.

Epoch of maximum coefficient $= 9^h{\cdot}84$.

$(p\Delta T_{00})^2 = 0^s{\cdot}000232 - 0^s{\cdot}000171 \,.\, (0{\cdot}84)^2 = 0^s\,000111$, $p\Delta T_{00} = \pm 0^s{\cdot}011$.

At time T, $p\Delta T = \pm \sqrt{0^s{\cdot}000111 + 0^s{\cdot}000171 \,.\, (T - 9^h{\cdot}84)^2}$.

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On the Photographic Magnitude of Nova Aurigæ, as Determined at the Royal Observatory, Greenwich. II. By W. H. M. Christie, M.A., F.R.S., Astronomer Royal.

In the *Monthly Notices* for last March (vol. lii. p. 357) results for the photographic magnitude of *Nova Aurigæ* were given as determined up to March 9. Since then photographs have been taken up to April 1, when the photographic magnitude had fallen below 14, and again at the end of August and beginning of September, when the star had brightened. Further measures were also made of the earlier photographs, modifying slightly the results given in the previous paper. The measures were made and reduced in the manner explained in that paper, the magnitude of the *Nova* being inferred by comparison with four Argelander stars of 8–9 magnitude by means of the formula

$$m = 2{\cdot}5\,(\log t - 0{\cdot}97\sqrt{d}) + \text{const.}$$

given in the *Monthly Notices*, vol. lii. p. 146, the measures of diameter of the four comparison stars being used to determine

the value of the constant for each plate. Their magnitudes taken from Argelander are: B.D. +30°.944, 8·2; +30°.949, 8·2; +30°.938, 8·7; +30°.913, 8·7; and it is assumed that the mean magnitude of the four stars is 8·45.

The results are given in the accompanying Table I. The initials A.E., E.R., A.R., W.C., C. are those of Miss Everett, Miss Rix, Miss Russell, Mr. Christie, and Mr. Criswick respectively.

TABLE I.

Photographic Magnitude of Nova Aurigæ from Comparisons with Four Stars, 8–9 Mag.

1892.		A.E. Mag.	E.R. Mag.	A.R. Mag.	W.C. Mag.	C. Mag.	Mean Adopted Magnitude.
Feb.	1	$4{\cdot}29_1$	$4{\cdot}60_1$	$4{\cdot}51_1$	$4{\cdot}53_1$	$4{\cdot}56_1$	4·50
	2	$3{\cdot}71_8$	$3{\cdot}14_3$	$3{\cdot}75_8$	...	$3{\cdot}81_8$	3·69
	3	$3{\cdot}69_8$	$3{\cdot}45_8$	...	$3{\cdot}60_3$	...	3·57
	12	$4{\cdot}23_4$	$3{\cdot}66_4$	...	$3{\cdot}46_3$	...	3·81
	13	$4{\cdot}50_8$	$4{\cdot}28_8$	$4{\cdot}37_3$	...	...	4·39
	18	$3{\cdot}99_8$	$3{\cdot}72_6$	$3{\cdot}95_8$	...	$4{\cdot}15_5$	3·94
	22	$4{\cdot}83_5$	...	$4{\cdot}34_8$	...	...	4·61
Mar.	7	$5{\cdot}05_8$	...	...	...	...	5·05
	9	$6{\cdot}30_7$	...	...	...	...	6·30
	10	$6{\cdot}77_2$	...	$6{\cdot}50_2$	...	...	6·64
	14	$8{\cdot}10_2$	...	$7{\cdot}87_1$	...	...	8·02
	15	$8{\cdot}03_3$	...	$7{\cdot}86_3$	...	...	7·95
	15	$8{\cdot}64_3$	...	$8{\cdot}62_3$	...	...	8·63
	18	$9{\cdot}47_2$	...	$9{\cdot}61_3$	...	...	9·55
	18	$9{\cdot}03_2$	...	$9{\cdot}47_3$	...	...	9·25
	19	$10{\cdot}03_3$	...	$10{\cdot}08_3$	...	...	10·06
	24	$11{\cdot}78_2$	...	$11{\cdot}27_2$	...	...	11·53
	28	$12{\cdot}48_3$	...	$13{\cdot}26_3$	...	$11{\cdot}68_2$	12·57
	30	$13{\cdot}08_2$	...	$13{\cdot}63_2$	...	...	13·36
Apr.	1	$14{\cdot}53_1$	...	$14{\cdot}21_1$	...	...	14·37
Aug.	30	$11{\cdot}63_2$	...	$12{\cdot}47_2$	$11{\cdot}77_2$	$11{\cdot}24_2$	11·78
Sept.	3	$11{\cdot}72_2$	...	$13{\cdot}11_2$	...	...	12·42
	5	...	...	$12{\cdot}55_3$	...	...	12·55
	6	$11{\cdot}73_4$	...	$12{\cdot}07_4$	...	...	11·90

The number of images of the *Nova* measured on each day is indicated by the suffix, the exposures ranging generally from 15^s to 12^m, as shown in the previous paper. This scale of exposures was, however, to some extent modified when the *Nova* got

too faint to be shown with the short exposures, and the following is a list of the exposures from March 19: March 19 and 24, 12^m, 4^m, 1^m; March 28, 12^m, 6^m; March 30, 20^m, 10^m, 30^s, 15^s; April 1, 30^m, 15^m, 30^s, 15^s; August 30 and September 3, 12^m, 4^m, 1^m; September 5, 12^m, 5^m, 4^m, 1^m; September 6, $8\frac{1}{2}^m$, 4^m, $2\frac{1}{4}^m$, 1^m, 30^s. On March 30 the *Nova* was shown with an exposure of 10^m, on April 1 with an exposure of 30^m, and on September 6 with an exposure of 1^m.

On March 15 and 18 two sets of exposures were given, the first with the *Nova*, and the second with the 5·7 mag. star B.D. +30°·898, at the centre of the plate, the *Nova* in the second set being about 60′ from that centre. These plates were taken to test whether distance from the centre would appreciably affect the determination of photographic magnitude.

The following are the values of photographic magnitude of B D + 30°·898 deduced in the two cases:—

Star 60′ from centre of plate.

Exposure.	1892 March 15, Plate 293. A.E.	A.R.	March 18, Plate 296. A.E.	A.R.
12^m	4·79	4·59	4·41	4·50
30^s	4·51	4·36	4·31	4·29
15^s	4·06	3·96	4·24	4·24
Mean of 3 ...	4·45	4·30	4·32	4·34
Mean of all exposures				4·36

Star at centre of plate.

12^m	4·39	4·31	4·84	4·34
30^s	4·24	4·11	3·91	4·22
15^s	4·11	3·96	3·99	3·97
Mean of 3 ...	4·25	4·13	4·25	4·18
Mean of all exposures				4·20

In connection with these measures it may be of interest to give the value of the constant deduced from each plate (the meaning of which has been explained in the previous paper, p. 364), Table II., and the results obtained for the photographic magnitudes of the four comparison stars referred to the mean of the four, which is assumed from Argelander to be 8·45, Tables III. and IV.

In explanation of the small values of the constant in some cases, it is to be remarked that several of the nights on which the photographs were taken were cloudy or hazy. This was the case on March 7, 9, 10, 14, and 15.

TABLE II.

Values of the Constant for each Plate from Measures of the Four Comparison Stars, 8–9 Mag.

1892.	A.E. Const.	E.R. Const.	A.R. Const.	W.C Const.	C. Const.	Mean Value of Constant.
Feb. 1	$10\cdot22_1$	$10\cdot30_1$	$9\cdot86_1$	$10\cdot23_1$	$10\cdot71_1$	10·26
2	$9\cdot05_3$	...	$8\cdot64_3$	...	$9\cdot24_3$	8·98
	$8\cdot43_2$	...	$8\cdot32_2$	...	$8\cdot71_2$	8·49
	$9\cdot51_3$	$9\cdot23_3$	$9\cdot27_3$	...	$9\cdot87_3$	9·47
3	$9\cdot15_3$	$8\cdot74_3$	...	...	...	8·95
	$8\cdot55_2$	$8\cdot12_2$	...	...	...	8·34
	$8\cdot77_3$	$8\cdot42_3$	...	$8\cdot61_3$	...	8·60
12	$9\cdot28_3$	$8\cdot65_3$	...	$8\cdot65_3$	...	8·86
	$8\cdot82_1$	$8\ 86_1$	...	...	...	8·84
13	$8\cdot60_2$	$8\cdot46_2$	...	...	...	8·53
	$8\cdot53_3$	$7\cdot96_3$	$8\cdot04_3$	...	...	8·18
	$8\cdot36_3$	$7\cdot71_3$	...	...	...	8·04
18	$9\cdot07_3$	$9\cdot01_3$	$9\cdot23_3$	...	...	9·10
	...	...	$9\cdot56_2$	...	$9\cdot89_2$	9·73
	$9\cdot24_3$	$9\cdot22_3$	$9\cdot38_3$	...	$9\cdot55_3$	9·35
22	$9\cdot70_3$	...	$9\cdot41_3$	...	...	9·56
	...	...	$9\cdot74_2$	...	...	9·74
	$9\cdot96_3$	...	...	...	...	9·96
Mar. 7	$8\cdot82_3$	...	...	...	...	8·82
	$8\cdot34_3$	...	...	...	...	8·34
9	$8\cdot96_3$	...	...	...	...	8·96
	$8\cdot35_4$	...	...	...	...	8·35
10	$7\cdot47_2$	...	$7\cdot29_2$	...	...	7·38
14	$6\cdot19_1$	...	$6\cdot22_1$	...	...	6·21
15	$8\cdot84_3$	...	$8\cdot69_3$	...	...	8·77
	$8\cdot45_2$	...	$8\cdot21_2$	...	...	8·33
18	$9\cdot19_3$	...	$9\cdot12_3$	...	...	9·16
	$9\cdot04_3$	...	$8\cdot81_3$	...	...	8·93
19	$9\cdot23_3$	...	$9\cdot18_3$	...	...	9·21
24	$9\cdot10_3$	...	$8\cdot67_3$	...	...	8·89
28	$8\cdot54_2$	...	$8\cdot55_2$	...	$8\cdot69_2$	8·59
	$8\cdot37_2$	...	$8\cdot36_2$	...	...	8·37
30	$9\cdot46_4$	...	$9\cdot58_4$	...	...	9·52
Apr. 1	$8\cdot83_4$	...	$8\cdot83_4$	...	...	8·83
Aug. 30	$9\cdot59_3$	...	$9\cdot94_3$	$9\cdot63_3$	$9\cdot78_3$	9·74
Sept. 3	$9\cdot18_3$	...	$9\cdot58_3$	...	...	9·38
5	...	...	$10\cdot03_1$	...	...	10·03
6	$9\cdot43_4$	...	$9\cdot53_4$	...	...	9·48
	$8\cdot90_1$	...	$9\cdot25_1$	...	...	9·08

Table III.

Photographic Magnitudes of the Four Comparison Stars, referred to the Mean of the Four.

Date. 1892.	Measurer.	B.D. +30° 944.	Mean.	+30° 949.	Mean.	+30° 938.	Mean.	+30° 913.	Mean.
Feb. 1	A.E.	7.99_1		8.31_1		8.81_1		8.47_1	
	E.R.	8.05_1	7.97	8.27_1	8.25	8.80_1	8.83	8.67_1	8.67
	A.R.	7.88_1		8.18_1		8.88_1		8.86_1	
2	A.E.	7.89_8		8.40_8		8.67_8		8.84_8	
	E.R.	7.91_3	7.92	8.49_3	8.35	8.63_3	8.68	8.78_3	8.85
	A.R.	7.96_3		8.24_8		8.71_8		8.89_3	
3	A.E.	8.06_8	7.99	8.54_8	8.51	8.61_8	8.61	8.74_7	8.80
	E.R.	7.91_8		8.48_8		8.60_8		8.86_7	
12	A.E.	7.97_4	8.01	8.24_4	8.19	8.64_4	8.74	9.03_3	8.95
	E.R.	8.04_4		8.13_4		8.83_4		8.86_3	
13	A.E.	8.03_8		8.30_8		8.65_8		8.84_8	
	E.R.	8.00_8	8.02	8.32_8	8.24	8.59_8	8.65	8.88_8	88·5
	A.R.	8.05_3		8.17_3		8.79_3		8.80_3	
18	A.E.	7.84_6		8.10_6		8.70_6		9.16_6	
	E.R.	7.93_6	7.84	7.87_6	8.01	8.68_6	8.71	9.34_6	9.25
	A.R.	7.78_8		8.03_8		8.75_8		9.24_8	
22	A.E.	8.00_6	8.42	8.24_6	8.22	8.78_6	8.79	8.78_6	8.82
	A.R.	8.93_5		8.19_5		8.80_5		8.87_5	
Mar. 7	A.E.	7.84_6	7.84	8.37_6	8.37	8.72_6	8.72	8.89_6	8.89
9	A.E.	8.04_7	8.04	8.27_7	8.27	8.63_7	8.63	8.86_7	8.86
10	A.E.	7.82_2	7.87	8.39_2	8.46	8.56_2	8.55	9.05_2	8.95
	A.R.	7.92_2		8.52_2		8.53_2		8.85_2	
14	A.E.	7.77_2	7.77	8.12_1	8.02	8.59_1	8.68	9.32_1	9.34
	A.R.	7.77_1		7.92_1		8.77_1		9.35_1	
15	A.E.	8.13_3	8.19	8.59_2	8.38	8.81_2	8.80	8.43_3	8.53
	A.R.	8.24_3		8.16_2		8.78_2		8.63_3	
15	A.E.	...		...		...		9.20_1	8.87
	A.R.	...		...		...		8.71_2	
18	A.E.	7.49_3	7.50	8.46_3	8.54	8.65_3	8.67	9.21_3	9.11
	A.R.	7.51_3		8.61_3		8.69_3		9.01_3	
18	A.E.	...		...		...		8.70_3	8.70
	A.R.	...		...		...		8.70_3	

Date. 1892.	Measurer.	B.D.+30° 944.	Mean.	+30° 949.	Mean	938.	Mean.	913.	Mean.
Mar. 19	A.E.	$7{\cdot}78_3$	7·85	$8{\cdot}29_3$	8·27	$8{\cdot}74_3$	8·72	$8{\cdot}99_3$	8·98
	A.R.	$7{\cdot}91_3$		$8{\cdot}24_3$		$8{\cdot}69_3$		$8{\cdot}97_3$	
24	A.E.	...		...		...		$8{\cdot}70_3$	8·70
	A.R.	...		...		...		$8{\cdot}70_3$	
28	A.E.	$8{\cdot}05_4$	8·00	$8{\cdot}52_4$	8·33	$8{\cdot}85_4$	8·83	$8{\cdot}65_4$	8·78
	A.R.	$7{\cdot}95_4$		$8{\cdot}13_4$		$8{\cdot}80_4$		$8{\cdot}91_4$	
30	A.E.	$8{\cdot}03_4$	8·06	$8{\cdot}04_4$	8·17	$8{\cdot}77_4$	8·72	$8{\cdot}98_4$	8·86
	A.R.	$8{\cdot}09_4$		$8{\cdot}30_4$		$8{\cdot}67_4$		$8{\cdot}73_4$	
Apr. 1	A.E.	$7{\cdot}95_4$	7·95	$8{\cdot}36_4$	8·25	$8{\cdot}80_4$	8·86	$8{\cdot}67_4$	8·73
	A.R.	$7{\cdot}95_4$		$8{\cdot}13_4$		$8{\cdot}91_4$		$8{\cdot}79_4$	
Aug. 30	A.E.	$8{\cdot}05_3$	$8{\cdot}05_3$	$8{\cdot}36_3$	$8{\cdot}35_3$	$8{\cdot}76_3$	8·76	$8{\cdot}65_3$	8·68
	A.R.	$8{\cdot}04_3$		$8{\cdot}33_3$		$8{\cdot}75_3$		$8{\cdot}70_3$	
Sept. 3	A.E.	$8{\cdot}06_3$	8·03	$8{\cdot}24_3$	8·24	$8{\cdot}68_3$	8·69	$8{\cdot}84_3$	8·86
	A.R.	$7{\cdot}99_3$		$8{\cdot}24_3$		$8{\cdot}69_3$		$8{\cdot}87_3$	
5	...	...		...		...		...	
	A.R.	$7{\cdot}75_4$	7·75	$8{\cdot}69_4$	8·69	$8{\cdot}62_4$	8·62	$8{\cdot}83_4$	8·83
6	A.E.	$7{\cdot}89_5$	7·85	$8{\cdot}03_5$	8·11	$8{\cdot}89_5$	8·81	$9{\cdot}01_5$	8·95
	A.R.	$7{\cdot}81_5$		$8{\cdot}18_5$		$8{\cdot}72_5$		$8{\cdot}89_5$	

TABLE IV.

Mean Photographic Magnitudes of the Four Comparison Stars.

Measurer.	1st Star. B.D.+30°. No. 944.	2nd Star. +30°. No. 949.	3rd Star. +30°. No. 938.	4th Star. +30°. No. 913.
A.E.	$7{\cdot}95_{89}$	$8{\cdot}31_{88}$	$8{\cdot}71_{88}$	$8{\cdot}85_{94}$
E.R.	$7{\cdot}96_{30}$	$8{\cdot}26_{30}$	$8{\cdot}65_{30}$	$8{\cdot}95_{28}$
A.R.	$7{\cdot}91_{64}$	$8{\cdot}24_{63}$	$8{\cdot}74_{63}$	$8{\cdot}88_{72}$
W.C.	$7{\cdot}97_{10}$	$8{\cdot}28_{10}$	$8{\cdot}74_{10}$	$8{\cdot}80_{8}$
C.	$7{\cdot}92_{19}$	$8{\cdot}42_{19}$	$8{\cdot}67_{19}$	$8{\cdot}80_{19}$
Mean of 1st 3 Observers' Measures	$7{\cdot}94_{183}$	$8{\cdot}28_{181}$	$8{\cdot}71_{181}$	$8{\cdot}88_{194}$
Mean of all the Measures.	$7{\cdot}94_{212}$	$8{\cdot}29_{210}$	$8{\cdot}71_{210}$	$8{\cdot}87_{221}$

The results for photographic magnitude of the four comparison stars may serve to show the degree of consistency which may be expected in determinations of magnitude deduced from measures of diameter of star-disks.

Royal Observatory, Greenwich:
1892 *November* 11.

Estimations of Magnitude of Nova Aurigæ, made with the Barclay Equatoreal, at the Radcliffe Observatory, Oxford.

(*Communicated by E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.*)

1892.	h	Observer.	Power of Eye-piece used.	Observed Magnitude of *Nova*.	Comparison Stars.	Remarks.
Sept. 8	13	R.	85	9·5	*a*, *k*, *h*	Moonlight.
13	12	R.	„	9·5	*a*, *k*, *h*	
15	12	R.	„	9·4	*a*, *k*, *h*	*Nova* possibly a trifle brighter than on September 13.
17	11	R.	„	9·6	*a*, *k*, *h*	
24	12	W.	„	9·9	*a*, *k*, *h*, *g*, *i*	
28	11	R.	„	9·4	*a*, *k*, *h*	
30	12	R.	„	9·6	*a*, *k*, *h*	
Oct. 5	12	R.	„	9·5	*a*, *k*, *h*	Moonlight.
7	11	R.	„	9·5	*a*, *k*, *h*	
10	10	P.	„	9·5	*a*, *k*, *h*	Moon near. *Nova* at times nearly as faint as *a*.
17	12	W.	„	10·0	*a*, *k*, *h*, *g*, *i*	
„		„	100	9·9	*a*, *g*, *i*	Images not sharp with any power, but ξ is visible.
„		„	180	9·9	*a*, *k*, *h*, *g*, *i*	

Estimations of Magnitude of Nova Aurigæ.—(continued).

1892.	h	Observer.	Power of Eye-piece used.	Observed Magnitude of *Nova*.	Comparison Stars.	Remarks.
Oct. 18	11	R.	85	9·6	*a*, *k*, *h*	
19	11	W.	"	9·7	*a*, *k*, *h*, *g*, *i*	The contrast between the *Nova* and *a* is, I believe, stronger to-night than on October 17.
25	11	R.	"	9·8	*a*, *k*, *h*	*Nova's* image is dull.
29	11	R.	"	9·7	*a* *k*, *h*	The image of the *Nova* is rather dull.
"		"	180	9·6	*a*, *k*, *h*	There is a slightly greater difference in magnitude between the *Nova* and *a* with power 180 than with 85.

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson.

The comparison star *h* was generally observed to be 0·1 of a magnitude *brighter* than *k*. The exceptions were:—September 24, fainter than *k*; September 30, equal to *k*; October 19, 0·2 fainter than *k*; October 25 and 29, equal to *k*.

The adopted magnitudes of the comparison stars are given in the *Monthly Notices* of the R.A.S., vol. lii., page 431, and depend fundamentally upon the magnitude assigned by Argelander to the star *k* (D.M. + 30°, No. 924), viz. 9·5.

Radcliffe Observatory, Oxford:
1892 *November* 10.

Nova Aurigæ. By E. E. Barnard, M.A.

The first time I ever saw the object with the 36-inch was 1892 August 19. As soon as I saw it I was struck with the fact that it was really a very small nebula, "some 5″ in diameter," with a 10th-magnitude stellar nucleus. The nebulosity was very dense and whitish, and with a low power might escape notice. A setting of the wires gave the diameter of the nebulosity as 3″. The star nucleus was from $0^{m}.1$ to $0^{m}.2$ less than the star F of Mr. Burnham's diagram (*Monthly Notices*, vol. lii., No. 6). But with low power, as a whole, the nebula and nucleus were brighter than that star. At every observation since the nebulosity has been a striking object—the colour of nebula and nucleus being a bluish white—quite in contrast to the star F, which has appeared slightly yellow.

The light seems to have been declining very slowly. At the last observation, October 23, the nucleus was fully one magnitude less than F, and the nebulosity seemed less bright and was smaller in extent. The bluish-white colour was still strikingly marked.

To detect any motion perpendicular to the line of sight I have repeated Mr. Burnham's measures of last spring with two of his stars, so selected as to show motion if it existed.

Here are the observations, all made with the micrometer of the 36-inch:—

	A *and* E.			A *and* F.	
	°	″		°	″
1892·64	323·3	74·24	1892·64	32·6	85·03
·66	323·5	74·41	·66	32·8	84·76
·67	323·5	74·64	·67	32·7	84·87
·70	323·5	74·75	·70	32·6	85·04
1892·67	323·5	74·51 B4*n*		32·7	84·92 B4*n*

Mr. Burnham's measures of the same stars are:—

	A *and* E.			A *and* F.	
1892·14	323°·6	74″·24 *β*3*n*	1892·12	32°·4	85″·05 *β*4*n*

A comparison of these measures do not show with certainty any motion in A. But the distance A E seems to be increasing. If this is real, and it seems to be so, it is strange that before my observations, it is not apparent, as compared with those of Mr. Burnham. Measures will be made to decide whether this motion is real, and if so, as to whether it is in A or E.

Mount Hamilton:
1892 *October* 24.

Discovery of a Comet by Photography. By E. E. Barnard, M.A.

On October 12 I made an exposure on the Milky Way near and west of α *Aquilæ* of 4 hours 20 minutes' duration with the Willard lens.

Upon developing the plate I found a distinct hazy trail near the middle of it, and about a quarter of a degree long. By this time the position of the object was too near the horizon to make a search for it. The next night (13th), as soon as it was dark enough, a search was made with the 12-inch, and the object was found nearly a degree south-east of the position on the photograph. A few minutes' observation showed it to be a comet in motion to the south-east. The comet was very faint in the 12-inch, about the thirteenth magnitude, round, and but little brighter in the middle. It has been carefully observed at every opportunity since.

This object is an exact representative of Class I. of short-period comets, very much resembling in appearance D'Arrest's comet.

The micrometer position on October 13 was—

1892 October 13^d 7^h 12^m 29^s Mount Hamilton M.T.

App. $\alpha = 19^h\ 33^m\ 57^s{\cdot}56$

App. $\delta = +12^\circ\ 30'\ 5''{\cdot}0$

From the faintness of the comet in the telescope, and the strength of its trail in the plate, it is evident that its light is mainly actinic. The plate used was a Cramer "Lightning," a very rapid and fine plate.

Mount Hamilton:
1892 *October* 24.

Note on the Period and Distance of the Fifth Satellite of Jupiter. By E. E. Barnard, M.A.

This satellite was discovered here by the writer at midnight, 1892, September 9, with the 36-inch equatoreal.

From the eastern elongations of September 10 and October 21 the following periodic time results: $11^h\ 57^m\ 20^s{\cdot}5$. Hourly motion $30^\circ{\cdot}111$.

The period of $17^h\ 36^m$ distributed in Europe was an error in telegraphic transmission. The period of $11^h\ 50^m$ sent later was erroneously derived from the observed distances of the satellite.

From seven eastern observed elongations the distance of the satellite (at east elongation) is $48''{\cdot}094$ (at 5.20). This corresponds to a distance from *Jupiter's* centre of 112,510 miles. The few observed western elongations give a distance about

1″ less than this, and there is evidently sensible ellipticity to the orbit.

At present the satellite is assumed to be of the 13th magnitude. Under the most favourable conditions it has not been possible to see the shadow of this object when in transit. From these and other considerations the satellite is probably not over 100 miles in diameter. Taking everything into consideration the brightness at east and west elongations is the same.

Mount Hamilton:
1892 *October* 24.

P.S.—Following are two of the last observed *east elongations* of the satellite:—

1892.	d	h	m	
Oct.	21	17	2·8	G.M.T. computed from measures before and after elongation.
	23	16	49·0	" " " "

The measured distance at east elongation of the 23rd was—

62″·90

October 26.

On the Sidereal Period of the New Satellite of Jupiter.
By the Rev. A. Freeman, M.A.

Upon examination of Professor E. E. Barnard's most important paper upon the "Discovery and Observation of a Fifth Satellite of Jupiter," published in No. 275 of the *Astronomical Journal*, for October 4, 1892, it seems probable that an error has been made in deducing the period from the concluded apparent distances of the satellite at its elongations, September 10, 12, and 14. Professor Barnard employs the formula—

$$P = p\sqrt{\frac{m}{M}\cdot\frac{R^3}{r^3}},$$

in which he states that m is the mass of the Earth, and M that of *Jupiter*, p and r the periodic time and geocentric radius of our Moon, P and R the periodic time and jovicentric radius of the new satellite. But, if he had desired to compare the period with that of our Moon, he ought to have employed the formula,

$$P = p\sqrt{\frac{m+m^1}{M+m_0}\cdot\frac{R^3}{r^3}},$$

in which $m^1 = \frac{1}{81}m$ (nearly) is the mass of the Moon, and m_0 is the mass of the new satellite, so small as to be neglected in comparison with the mass of *Jupiter*. Unless, therefore, the "*mass of the Earth*" meant by Mr. Barnard includes that of the Moon also, his resulting period is manifestly and decidedly too small.

I prefer to compare the motion of the new satellite with that of the first hitherto known satellite of *Jupiter*.

The exact formula to be employed is

$$\frac{P}{P_1} = \sqrt{\frac{M+m_1}{M+m_0} \cdot \frac{R^3}{R_1^3}},$$

where M is the mass of *Jupiter*, m_0 and m_1 the masses of the new and first satellites, R and R_1 their jovicentric radii. We can, however, safely neglect the masses of both satellites, and use the simple expression—

$$P = P_1 \left(\frac{R}{R_1}\right)^{\frac{3}{2}}.$$

From Barnard's apparent elongations, September 10, 12, 14, viz.: 61″·04, 61″·55, 61″·50, which correspond to G.M.T. $20^h\ 53^m$, $20^h\ 38^m$, $20^h\ 24^m$ (with sufficient accuracy), on the respective dates, I find by multiplying the apparent elongations in seconds of arc by the concluded geocentric radii of *Jupiter*, taken from the *Nautical Almanac*, and dividing by 5·202800, the heliocentric mean radius of *Jupiter*, that 47″·9613, 48″·1666, 48″·0217 are the corresponding elongations of the new satellite as viewed from the Sun at the mean distance of *Jupiter* on September 10, 12, 14. The mean of these three is 48″·04993.

Now Bessel and Schur have given 111″·7360 and 111″·6523 for the mean elongation of Sat. I. of ♃, at ♃'s mean distance from the Sun. The mean of these two measures is 111″·6942. Moreover, the mean sidereal period of Sat. I. is 1·7691378 mean solar days. Hence we have

$$P = \left(\frac{48{\cdot}04993}{111{\cdot}6942}\right)^{\frac{3}{2}} \cdot 1^d{\cdot}7691378,$$

whence

$$P = 0^d{\cdot}4991775$$
$$= 11^h\ 58^m\ 48^s{\cdot}9$$

as the sidereal period of the new satellite. It is remarkable that this differs little from $11^h\ 59^m$, the period which is accepted by Mr. S. W. Burnham in a communication to the *Chicago Academy of Sciences*, at their meeting, 1892 October 4. (See *Observatory*, 1892 November.)

Further measures of elongation distances will no doubt soon be published by Mr. Barnard, and may be used to correct the period found above.

Murston Rectory:
1892 *November* 9.

Addendum.

Taking the necessary data from Professor W. Harkness's *The Solar Parallax and the Related Constants*, and employing the second formula in the foregoing paper, I find—

$$\frac{P}{27^d\cdot32166116} = \left(\frac{1047\cdot55}{327214}\right)^{\frac{1}{2}}\left(\frac{5\cdot2028\times92796950\times\sin 48''\cdot05}{238854\cdot75}\right)^{\frac{3}{2}}$$

$$= 0\cdot5002246 \text{ days}$$

$$= 12^h\ 0^m\ 13^s\cdot4.$$

An error of even $\frac{1}{20}$th of a second of arc in the assumed distance $48''\cdot05$ makes an appreciable difference in the resulting period. The best way of obtaining the true result is to infer it from the number of revolutions and parts of a revolution made by the satellite between the times of two distant elongations, as has now been done by Mr. A. Marth and Professor Barnard, whose periods thereby derived agree within half a second of time. The period found by Mr. Marth is $11^h\ 57^m\cdot33$.

1892 *November* 15.

Enlarged Star and Moon Photographs. By H. C. Russell, B.A., F.R.S.

In making another enlargement of the photograph of the stars and nebulæ about η *Argûs* to replace the one destroyed in transit, it seems desirable to make it upon the same scale as Herschel's beautiful picture of that object published in the Cape observations, thus ensuring convenient comparison. This involved enlarging the original photograph, the scale of which is 2·3 ins. to 1°, up to 15 ins. to 1°, and the result is a strong testimony to the quality of the original negative. I have sent both positive and negative on paper. The paper negative of course involved making a positive by contact printing, in which much detail is lost. A comparison of these photographic enlargements with Herschel's drawing is very suggestive, both in regard to the difference in delineation and extent of the nebula by the eye and the sensitive plate, particularly in the great mass of detail which the camera brings out in the denser parts, and also the vastly greater number of stars, probably ten times as many in the photograph as in the drawing. (The original negative was exposed $5\frac{3}{4}$ hours.) I send also an enlargement of the same object (η *Argûs*) from a negative taken with a 6-inch diameter Dallmeyer portrait lens, and 8 hours exposure, on a scale of 0·556 in. = 1°, enlarged to 3 ins. = 1°. This enormously extends the area of the nebula, and shows that the dark markings which begin at the centre of the mass extend in curiously meandering lines to great distances, in several places enclosing nearly circular spaces. Looking at this photograph the nebula seems to spread out almost without limit, as indicated by the dark lanes which bring it into prominence; but the more definite parts, about which the connection with the central mass cannot be doubted, cover a space measured by 2° in R.A. and 3° in Decl., while the photograph taken with the star camera and $5\frac{3}{4}$ hours'

exposure is less than 1° in R.A. and less than $1\frac{1}{4}$° in Decl., an area as nearly as possible of 1°; while in the one taken with the portrait camera it covers an area of at least 6°.

The photograph must speak for itself, but there is one feature of special interest. Herschel's lemniscate—at least the greater part of it—seems quite black to the eye aided by large telescopes, and the same in the photograph with the star camera, but it will be seen that in the one with the portrait camera it is not without nebulous light, and the prolonged exposure has brought it out sufficiently to fill up the dark space completely, while the dark oval which Herschel describes so carefully at R.A. − 100 and Decl. + 900 of his drawing is in the photograph absolutely dark, and thrown into great prominence by the brilliance of the nebulous light around it. I have also sent two enlargements of portions of the Moon, one showing *Copernicus* nearly 1 inch in diameter (scale for whole Moon 34 ins.), with corresponding detail inside and outside the crater; this is from a negative taken direct, $5\frac{1}{2}$ ins. in diameter: also a portion of the Apennine mountains, on a scale of 65 ins. = diameter of the Moon. The negative for this was taken direct on a scale of 20 ins. to diameter of Moon. Both these Moon pictures contain more detail than any I have seen; the latter especially brings the precipices, clefts, and valleys of the Apennines into striking prominence, on a scale which makes *Archimedes* $1\frac{3}{4}$ in. in diameter.

Sydney Observatory:
1892 *September* 17.

The Motion of ζ Cancri. By S. W. Burnham, M.A.

In a paper entitled "Invisible Double Stars" (*Monthly Notices*, April, 1891) I gave the result of an investigation of the observed positions of the star C of this system. From this it appeared that, while the observed places of this star were apparently arranged in somewhat regular groups, all of the stars of the same class which were examined showed the same tendency, and with about the same regularity. The question to be solved was whether this apparent want of uniformity in the motion of the star was to be ascribed to the disturbance produced by some unknown and invisible body, or to the ordinary errors of observation. While there is nothing, perhaps, improbable in the theory that non-luminous stars may exist throughout space, and may be components of binary systems, still it is at present a speculation at best, and it is obvious that it should be adopted as an explanation of actual observations only when the ordinary ways of accounting for apparent discordances have been positively shown to be insufficient. There would be less room for debate if ζ *Cancri* were the only example of this kind, but I have shown that in other stars, selected at random from those having an angular movement around their primaries of about the same

amount, all show without exception the same apparently variable motion, more or less prominently. This suggests the possibility, at least, that the explanation may be found in the errors of observation. Otherwise we are forced to admit the existence of many more "dark suns" than one could reasonably expect to find in a single class of binary stars.

I also suggested that the best way to determine this interesting question in the case of *ζ Cancri* would be to measure C from some outside star, entirely disconnected from the triple system. By keeping up regularly for a few years a careful system of measures, it could doubtless be shown whether or not the motion of C was uniform. It seemed to me that measures of the difference of the declinations of C and some convenient star in the vicinity would be most likely to avoid the errors which to some extent would certainly be found in measures connecting C with the close pair, A B; and I called attention to a $7\frac{1}{2}$ *m* star (Lalande 12262) about 2^m following *ζ Cancri*, and 1′·5 north, as being suitable for this comparison and also to a 9 *m* D M. star nearly following, which could be used for angular measures only. Obviously measures of the difference of declination are superior to any other for determining change. With the telescope stationary the bisections can be made with an accuracy not attainable in direct measures of considerable distances. In this case the sole question to be determined, in the first instance, is whether any change in the relative positions of these two stars in declination is uniform. Change due to the proper motion of either star, or to the orbital movement of C about the close pair, can, of course, be wholly neglected, since that will be a constant quantity.

In the interest of the solution of this question I have put these suggestions in practice, and have made each year a careful set of measures of C, with reference to the star which follows, for the difference in declination; of C from A and B as separate stars; and of the angular direction of the small star, D M. (18°) 1870. The aperture in inches of the telescope employed is given in the last column.

C. *and* Ll. 12262.

1891·225	Diff. Decl. 103″·89	...	36
·227	104·05	...	36
·236	104·08	...	12
·241	103·99	...	36
		h m	
1892·057	103·80	Sid^{l}. Time 7 35	36
·085	103·72	8 00	36
·118	103·97	8 25	36
·153	103·99	8 00	36
·156	103·87	8 15	36

C. *and* D.M. (18°) 1870.

1891·181	Pos. Angle 108°17	...	12
·208	108·33	...	12
·214	108·14	...	12
·222	108·32	...	12
·225	108·28	...	36
·227	108·15	...	36
·239	108·31	...	36
·241	108·17	...	36
1892·057	107·90	Sid^{t}. Time 7 30	36
·156	108·25	8 00	36
·173	108·50	6 25	36
·186	108·35	8 10	36

A. *and* C.

1891·181	117°6	5″45	12
·214	117·2	5·49	12
·222	115·9	5·42	12
·225	117·3	5·57	36
·227	116·2	5·58	36
·239	115·5	5·52	36
1892·057	115·3	5·51	36
·153	116·5	5·41	36
·156	117·7	5·42	36
·186	117·3	5·58	36

B. *and* C.

1891·181	128°1	5″52	12
·214	127·6	5·66	12
·222	128·5	5·56	12
·225	127·4	5·58	36
·227	127·7	5·61	36
·239	127·3	5·69	36
1892·057	127·4	5·66	36
·153	128·3	5·48	36
·156	127·6	5·52	36
·186	127·5	5·46	36

A. *and* B.

1892·153	32°·7	1″·04	36
·186	33·2	1·02	36
1892·17	33·0	1·03	

The mean results of the two sets of measures are as follows:—

C. *and* Ll. 12262.

1891·23	Diff. Decl. 104″·00	4*n*
1892·11	103·87	5*n*

C. *and* D.M. (18°) 1870.

1891·22	Pos. Angle 108°·23	8*n*
1892·14	108·00	4*n*

A. *and* C.

1891·22	116°·6	5″·50	6*n*
1892·14	116·7	5·48	4*n*

B. *and* C.

1891·22	127°·8	5″·60	6*n*
1892·14	127·7	5·53	4*n*

All of the measures were made near the meridian, and under favourable atmospheric conditions. I have not noted the sidereal time in the first observations of the distant stars, but the slight change due to refraction is of no practical consequence, and in any event it is essentially the same for all the observations. In the measures of C from the components of the close pair, high powers were always used, and A and B were widely separated; at the same time it is not easy, and perhaps impossible, to prevent the presence of a third star, within 1″ of that which is being measured, from having some effect in the placing of the wires both in angle and distance. I rely principally upon the measures of declination. It will be well, however, to continue all the measures of the stars used here; but I think it is important that the aperture and power used should be sufficient to observe the components of the close pair separately. I do not think measures of C from A B as one star would have much value in determining whether or not the movement of the first-named star is variable.

Doubtless other observers who have taken an interest in this question of an invisible disturbing body have already commenced observations similar to those given here. I trust that this is so, and that they will be systematically continued until sufficient data are obtained to settle the point definitely by the best evidence of all.

Chicago: 1892 *October* 17.

On the Orbit of Σ 2525. By J. E. Gore.

A recent measure of this binary star made by Mr. Burnham with the 36-inch refractor of the Lick Observatory shows that the companion has described about 288° of its apparent ellipse since its discovery by Struve in 1830. I have computed the orbit by the Glasenapp-Kowalsky method, and find the following provisional elements:—

Elements of Σ 2525.

$P = 138{\cdot}54$ years.	$\Omega = 78°\ 19'{\cdot}5$
$T = 1887{\cdot}12$	$\lambda = 4°\ 19'$
$e = 0{\cdot}802$	$a = 0''{\cdot}75$
$i = 54°\ 0'$	$\mu = -2°{\cdot}5984$

The following is a comparison between the measures used in calculating the orbit and the positions computed from the above elements. Some of the measures are rather discordant.

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
		°	°	°	″	″	″
1830·43	Struve	255·9	257·3	−1·4	1·33	1·32	+0·01
1836·14	,,	255·5	255·5	0·0	1·30	1·28	+0·02
1840·56	O. Struve	251·8	254·1	−2·3	1·04	1·24	−0·20
1840·62	Dawes	255·5	254·1	+1·4	1·25	1·24	+0·01
1840·70	O. Struve	252·4	254·1	−1·7	1·28	1·24	+0·04
1840·84	,,	253·1	254·0	−0·9	1·52	1·24	+0·28
1842·41	Mädler	251·0	253·5	−2·5	0·82	1·21	−0·39
1843·69	,,	254·0	253·1	+0·9	0·95	1·20	−0·25
1854·63	O. Struve	246.8	248·5	−1·7	1·05	1·05	0·0
1856·61	Secchi	247·1	247·7	−0·6	0·85	1·01	−0·16
1865·22	Dembowski	240·8	242·3	−1·5	0·60	0·81	−0·21
1865·48	Engelmann	253·6	242·2	(+11·4)	0·73	0·80	−0·07
1865·64	Secchi	239·9	242·1	−2·2	0·40	0·80	−0·40
1865·76	O. Struve	241·5	242·0	−0·5	0·74	0·80	−0·06
1865·80	,,	242·4	242·0	+0·4	0·73	0·80	−0·07
1872·61	,,	234·0	234·8	−0·8	0·66	0·60	+0·06

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$
		°	°	°	″	″	″
1872·64	Wilson and Seabroke	232·6	234·8	−2·2	...	0·60	
1873·54	Ferrari	241·1	233·4	+7·7	...	0·57	
1873·57	„	225·8	233·3	−7·5	0·5	0·57	−0·07
1873·61	Dembowski	233·4	233·3	+0·1	0·6	0·57	+0·03
1873·65	Wilson and Seabroke	232·1	233·3	−1·2	...	0·57	
1874·75	„ „	237·8	231·2	+6·6	0·5	0·53	−0·03
1874·84	Gledhill	234·2	231·0	+3·2	0·48	0·52	−0·04
1875·65	Schiaparelli	232·1	229·4	+2·7	0·45	0·49	−0·04
1875·66	Wilson and Seabroke	233·6	229·4	+4·2	...	0·49	
1877·01	Schiaparelli	230·1	225·9	+4·2	0·37	0·43	−0·06
1877·82	Dembowski	238·0	223·7	(+14·3)	...	0·41	
1879·71	Hall	213·2	216·1	−2·9	0·33	0·32	+0·01
1880·61	Doberck	218·85	210·8	+8·05	...	0·28	
1880·67	Schiaparelli	217·8	210·5	+7·3	0·32	0·28	+0·04
1880·81	Doberck	201·16	209·8	−8·64	...	0·28	
1887·7	Schiaparelli	Single with 18-inch refractor				0·15	
1891·40	Burnham	343·4	342·8	+0·6	0·18	0·18	0·0
1892·422	„	328·3	328·3	0·0	0·27	0·21	+0·06

Assuming that the mass of the system is equal to the mass of the Sun, the "hypothetical parallax" would be

$$p = \frac{a}{P^{\frac{2}{3}}} = 0''{\cdot}028.$$

The magnitudes of the components are, according to Struve, 7·4, 7·6; and the approximate position of the star for 1880·0 is

R.A. $19^h\ 21^m{\cdot}7$

Decl. $+27°\ 8'$

It lies about $1\frac{1}{4}°$ *s.p.* *β Cygni.*

The Orbit of γ Coronæ Australis. By R. P. Sellors, B.A.

(*Communicated by H. C. Russell, B.A., F.R.S.*)

The general equation of the apparent ellipse was found by Glasenapp's method, and the geometrical elements deduced therefrom by the formulæ of Kowalsky. The dynamical elements were determined from five equations of mean motion.

Elements.

P = 121·24 years	☊ = 57° 57′
T = 1879·33	λ = 181° 5′
e = 0·33096	a = 2″·191
i = 35° 37	μ = −2°·9694

The following is a comparison between all the measures I have been able to collect, and the positions computed from the above elements :—

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_c$	No. of Nights.	ρ_o	ρ_c	$\rho_o - \rho_c$	No. of Nights.
		°	°	°		″	″	″	
1834·47	Herschel	37·1	37·9	−0·8	1				
35·55	„	36·8	36·2	+0·6	2				
36·43	„	34·5	34·9	−0·4	1				
37·21	„	...	...	...	...	2·66	2·61	+·05	6
37·43	„	32·7	33·3	−0·6	4				
47·32	Jacob	14·1	14·7	−0·6	2	2·30	2·21	+·19	2
50·46	„	5·9	7·1	−1·2	...	2·29	2·07	+·22	
51·54	„	4·5	4·3	+0·2	...	2·26	2·02	+·24	
52·49	„	2·2	1·7	+0·5	...	1·90	1·97	−·07	
53·52	„	359·1	358·7	+0·4	...	1·83	1·92	−·09	
53·708	Powell	358·6	358·1	+0·5	4				
54·26	Jacob	356·2	356·5	−0·3	3	1·71	1·89	−·18	2
54·782	Powell	355·6	354·9	+0·7	3				
55·768	„	352·9	351·7	+1·2	5				
56·441	Jacob	349·4	349·4	0·0	11	1·67	1·79	−·12	11
57·434	„	347·4	345·9	+1·5	8	1·61	1·75	−·14	8
58·200	„	343·4	343·1	+0·3	3	1·53	1·71	−·18	3
59·721	Powell	338·1	337·3	+0·8	4				
61·691	„	328·8	329·0	−0·2	4				
62·271	„	325·3	326·4	−1·1	5				
63·836	„	318·1	319·1	−1·0					
70·19	„	286·9	286·7	+0·2					
75·648	Schiaparelli	257·4	258·0	−0·6	4	1·45	1·45	·00	4
76·645	Howe	253·1	252·8	+0·3	1	1·67	1·46	+·21	1
77·430	Schiaparelli	248·4	248·7	−0·3	5	1·49	1·46	+·03	3
77·611	Howe	245·7	247·7	−2·0	3	1·37	1·46	−·09	3
77·687	Stone	249·4	247·3	+2·1	1				
78·491	Howe	242·9	243·2	−0·3	1	1·47	1·46	+·01	1
78·491	Stone	242·4	243·2	−0·8	1	1·22	1·46	−·24	1
79·695	Burnham	240·0	237·1	+2·9	1	0·87	1·47	−·60	1
80·457	Russell	233·1	233·2	−0·1	1	1·15	1·47	−·32	1
80·673	Hargrave	232·4	232·1	+0·3	1	1·32	1·47	−·15	1
81·720	Stone	225·5	226·8	−1·3	3	1·42	1·46	−·04	2
83·620	Wilson	217·7	217·0	+0·7	4	1·66	1·46	+·20	1
86·615	Pollock	200·6	201·5	−0·9	8	1·45	1·45	·00	8

Epoch.	Observer.	θ_o	θ_c	$\theta_o - \theta_o$	No. of Nights.	ρ_o	ρ_c	$\rho_o - \rho_c$	No. of Nights.
1886·704	Russell	203°·5	201°·0	+2°·5	1	1″·52	1″·45	+″·07	1
87·689	Pollock	196·6	195·9	+0·7	4	1·16	1·45	−·29	4
87·728	Tebbutt	196·2	195·7	+0·5	4	1·68	1·45	+·23	1
88·610	„	189·3	191·1	−1·8	6	1·71	1·45	+·26	3
88·707	Leavenworth	188·0	190·6	−2·6	1				
89·41	Burnham	185·4	186·9	−1·5	4	1·79	1·45	+·34	4
89·837	Tebbutt	185·4	184·7	+0·7	4	2·30	1·45	+·85	1
90·589	„	183·0	180·8	+2·2	4	1·61	1·46	+·15	4
90·647	Sellors	180·5	180·5	0·0	6	0·99	1·46	−·47	4
91·676	„	177·6	175·2	+2·4	4	1·33	1·47	−·14	3
91·711	Tebbutt	176·3	175·0	+1·3	9	1·53	1·47	+·06	4

Government Observatory, Sydney, New South Wales:
1892 *September* 5.

Observations of Brooks' Comet (d 1892) and Swift's Comet (a 1892) made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the East, or Sheepshanks equatoreal, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55.

Brooks' Comet.

Greenwich Mean Solar Time. 1892	Observer.	✓−✶ R.A.	Log factor of Parallax.	Corr. for Refraction.	✓−✶ N.P.D.	Log factor of Parallax.	Corr. for Refraction.	No. of Comps.	Appt. R.A.	Appt. N.P.D.	Comp. ✶
		m s		s	′ ″		″		h m s	° ′ ″	
Sept. 24 12 18 58	A. C.	+0 23·98	9·6160	−0·01	− 2 36·3	0·8100	−0·3	4	7 9 37·86	61 52 14·7	*a*
Oct. 1 12 12 31	L.	+0 36·63	9·6091	+0·05	+ 8 2·2	0·8148	+0·5	2	...	...	*b*
1 12 53 32	„	+0 33·63	9·6133	−0·04	−13 2·1	0·7848	+0·1	2	...	...	*c*
1 12 18 2	B.	+0 37·75	9·6106	+0·05	+ 7 43·7	0·8106	+0·3	2	...	...	*b*
1 12 45 34	„	+0 33·63	9·6135	−0·04	−13 19·1	0·7904	+0·1	2	...	...	*c*
14 12 53 23	„	+0 6·38	9·5965	−0·03	− 8 55·2	0·7955	−0·2	2	8 11 41·90	68 20 24·4	*d*
14 12 57 2	„	+0 44·38	9·5960	−0·03	− 8 37·8	0·7934	−0·2	2	8 11 42·67	68 20 33·8	*e*
14 13 1 33	„	+1 15·00	9·5951	−0·02	− 5 34·7	0·7906	−0·2	2	8 11 43·48	68 20 39·0	*f*
14 13 4 35	„	−0 59·00	9·5944	+0·03	+10 58·2	0·7887	+0·1	2	8 11 38·12	68 21 9·2	*g*
14 13 19 22	C. D.	−0 57·00	9·5898	+0·03	+11 1·9	0·7793	+0·1	2	8 11 40·12	68 21 12·9	*g*
14 13 25 26	„	+1 17·00	9·5874	−0·01	− 5 13·8	0·7756	−0·1	2	8 11 45·49	68 21 0·0	*f*
14 13 29 26	„	+0 48·25	9·5857	−0·02	− 8 25·6	0·7730	0·0	2	8 11 46·55	68 20 46·2	*e*
14 13 32 24	„	+0 11·63	9·5843	−0·02	− 8 23·9	0·7711	0·0	2	8 11 47·16	68 20 55·9	*d*
18 13 12 58	„	−0 10·19	9·5857	+0·01	+ 2 24·9	0·7897	+0·1	8	...	...	*h*
22 12 15 42	H.	−1 5·50	9·5858	+0·13	+11 34·5	0·8246	−0·1	4	8 39 19·70	72 18 3·7	*i*

Greenwich Mean Solar Time.	Observer.	✱−✱ R.A.	Log factor of Parallax.	Corr. for Refraction.	✱−✱ N.P.D.	Log factor of Parallax.	Corr. for Refraction.	No. of Comps.	Appt. R.A.	Appt. N.P.D.	Cmp. ✱
1892 d h m s		m s		s	′ ″		′		h m s	° ′ ″	
Oct. 22 12 29 0	H.	−2 40·25	9·5871	+0·05	+ 6 7·9	0·8182	−0·2	1	...	...	*k*
22 12 58 7	,,	+0 40·38	9·5836	−0·04	− 7 32·3	0·8041	+0·7	4	...	...	*l*
22 12 58 59	C. D.	−1 1·00	9·5840	+0·06	+12 44·1	0·8038	−1·3	3	8 39 24·13	72 19 12·1	*i*
22 13 15 38	,,	+0 43·25	9·5791	−0·02	− 6 51·2	0·7955	+0·9	2	...	...	*l*
23 12 19 0	A. C.	+0 26·15	9·5851	+0·09	+ 8 19·0	0·8242	+0·2	4	...	...	*m*
23 12 27 19	,,	+1 12·83	9·5857	−0·13	−13 39·6	0·8203	0·0	2	...	...	*n*
23 12 27 19	,,	+0 10·40	9·5857	+0·05	+ 4 45·7	0·8203	−0·1	2	...	...	*o*
25 13 34 13	B.	−0 46·87	9·5652	−0·04	−11 41·8	0·7930	−0·2	5	8 50 28·50	74 4 8·1	*p*
25 13 36 27	,,	−1 9·39	9·5647	+0·01	+ 4 37·5	0·7921	+0·1	7	8 50 25·80	74 4 54·5	*q*
Nov. 3 14 3 49	A. C.	−1 0·30	9·5345	−0·01	− 3 34·4	0·8074	−0·1	3	...	...	*r*
3 14 19 21	,,	+2 30·90	9·5203	−0·03	−11 36·7	0·8035	−0·1	1	9 25 13·17	80 16 48·5	*s*
3 14 9 42	T. H.	−0 58·45	9·5300	−0·01	− 3 27·8	0·8061	−0·1	2	...	...	*r*
6 13 48 31	B.	+0 57·75	9·5440	−0·03	− 7 56·4	0·8195	−0·3	3	9 37 20·54	82 38 37·5	*t*
6 13 55 38	,,	−3 7·80	9·5390	−0·03	− 8 37·8	0·8181	−0·2	3	9 37 22·20	82 39 1·3	*u*
6 15 3 24	,,	+5 59·30	9·4632	0·00	+ 0 48·6	0·8062	0·0	3	9 37 31·69	82 41 40·6	*v*
Swift's Comet.											
1892 d h m s		m s		s	′ ″		″		h m s	° ′ ″	
Oct. 23 10 58 51	A. C.	−0 21·65	9·2376	0·00	−14 57·0	0·2583	−0·1	2	23 47 14·11	48 59 58·6	*w*

Notes.

On Oct. 23 Swift's Comet was extremely faint and was only suspected; its close proximity to several faint stars increased the difficulty of accurate observation.

Brooks' Comet on Oct. 23 was large and round, with decided central condensation.

On Nov. 3 it was very faint owing to moonlight and mist. On Nov. 6 it was noted as fairly large, with a nucleus of 7·5 magnitude.

Assumed Mean Places of Comparison Stars.

Star's Name.	Mean R.A., 1892·0. h m s	Mean N.P.D., 1892·0. ° ′ ″	Authority.
a. 53 Geminorum	7 9 12·24	61 54 54·0	Paris Catalogue.
b. B.D. + 26° 1605	7 29 32·4	63 33·4	Bonn Observations.
c. B.D. + 26° 1607	7 29 45·9	63 54·4	,, ,,
d. W.B. (2) VIII.. 192	8 11 33·69	68 29 20·2	Weisse's Bessel.
e. W.B. (2) VIII., 173	8 10 56·46	68 29 12·3	,, ,,
f. Lalande, 16149	8 10 26·63	68 26 14·4	Paris Catalogue.
g. Lalande, 16236	8 12 35·23	68 10 11·1	,, ,,
h. B.D. + 19°, 2026	8 25 28·7	70 11·2	Bonn Observations.
i. Lalande 17260	8 40 23·18	72 6 28·4	Lalande.
k. B.D. + 17°, 1941	8 41 59	72 12·1	Bonn Observations.
l. B.D. + 17°, 1931	8 39 56	72 31·8	,, ,,
m. B.D. + 17°, 1943	8 42 24	72 44·0	,, ,,
n. B.D. + 17°, 1939	8 41 42	73 6 2	,, ,,
o. B.D. + 17°, 1945	8 42 42	72 46·7	,, ,,
p. o_1 Cancri	8 51 13·52	74 15 49·0	Greenwich Ten-Year Catalogue, 1880
q. o_2 Cancri	8 51 33·29	74 0 15·7	,, ,, ,,
r. B.D. + 9°, 2195	9 26 7·8	80 20·4	Bonn Observations.

Star's Name.	Mean R.A., 1892·0.	Mean N.P.D., 1892·0.	Authority.
	h m s	° ′ ″	
s. ω Leonis	9 22 40·41	80 28 23·2	Greenwich Ten-Year Catalogue, 1880, and Paris Catalogue.
t. Lalande, 19042	9 36 20·95	82 46 31·7	Paris Catalogue.
u. B.F., 1383	9 40 28·18	82 47 36·5	Greenwich Ten-Year Catalogue, 1880.
v. 10 Leonis	9 31 30·49	82 40 49·7	,, ,, ,,
w. Groombridge, 4155	23 47 33·08	49 15 19·6	Radcliffe Catalogue.

The following observations of Swift's Comet were made on the meridian with the Transit Circle:—

Greenwich Mean Solar Time.	Observer.	Appt. R.A.	Appt. N.P.D. (Corrected for Refraction and Parallax.)
1892. d h m s		h m s	° ′ ″
Sept. 17 12 30 53	A. C.	0 20 27·72	39 28 17·81
Sept. 24 11 54 34	,,	0 11 39·10	40 55 18·44

The corrections applied for parallax were 0·″06, 0·″17 respectively.

In computing these log Δ was taken as 0·2819 on September 17, 0·2907 on September 24, these values being interpolated from Archenhold's Ephemeris (*Astr. Nach.*, 3110).

On September 24 the comet was very faint, and was observed over one wire only in R.A.

The initials L., H., A. C., B., T. H., C. D., are those of Mr. Lewis, Mr. Hollis, Mr. Crommelin, Mr. Bryant, Mr. Hudson, and Mr. Davidson respectively.

Observations of Holmes' Comet (f 1892) made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the East, or Sheepshanks Equatoreal, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55.

Greenwich Mean Solar Time.	Observer.	☄ − ✶ R.A.	Log factor of Parallax.	Corr. for Refraction.	☄ − ✶ N.P.D.	Log factor of Parallax.	Corr. for Refraction.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. ✶
1892 Nov. d h m s		m s		s	′ ″		″		h m s	° ′ ″	
9 9 36 26	A. C.	−1 12·98	8·2200	0·00	+ 8 49·7	0·2983	+0·1	2	0 45 51·75	51 41 19·0	*a*
9 10 48 58	,,	−1 3·60	9·0446	0·00	+ 0 31·1	0·3542	0·0	3	...	...	*b*
9 11 22 53	,,	+1 22·40	9·3552	0·00	− 1 17·8	0·3818	0·0	2	0 45 53·02	51 41 29·6	*c*
10 6 17 48	L.	+1 17·13	9·5314	0·00	− 4 39·0	0·4866	−0·1	2	0 45 26·34	51 45 54·8	*d*
10 6 17 48	,,	−1 41·25	9·5314	−0·01	+13 43·0	0·4866	+0·1	2	0 45 23·46	51 46 12·2	*a*
10 6 25 3	A. C.	+1 18·33	9·5177	0·00	− 4 42·1	0·4751	−0·1	2	0 45 27·54	51 45 51·7	*d*
10 6 14 43	,,	−1 30·15	9·5368	0·00	+ 5 15·8	0·4903	+0·1	1	...	...	*b*

Comparison Stars.

	Star's Name.	R.A. 1892·0. h m s	N.P.D. 1892·0. ° ′ ″	Authority.
a	Lalande, 1444	0 47 1·73	51 32 55·0	Paris Catalogue, 1875.
b	B.D. + 38°, 128	0 46 51·3	51 40·5	Bonn Observations.
c	W. B. (2), 0, 1092	0 44 27·63	51 43 13·2	Weisse's Bessel.
d	W. B. (2), 0, 1083	0 44 6·22	51 50 59·8	,, ,,

Note.

The comet was very bright, about 5′ in diameter, with a stellar nucleus.

The initials L. and A. C. are those of Mr. Lewis and Mr. Crommelin respectively.

Royal Observatory, Greenwich:
1892 *November* 11.

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